January 1959
75¢

EMICONDUCTOR PRODUCTS

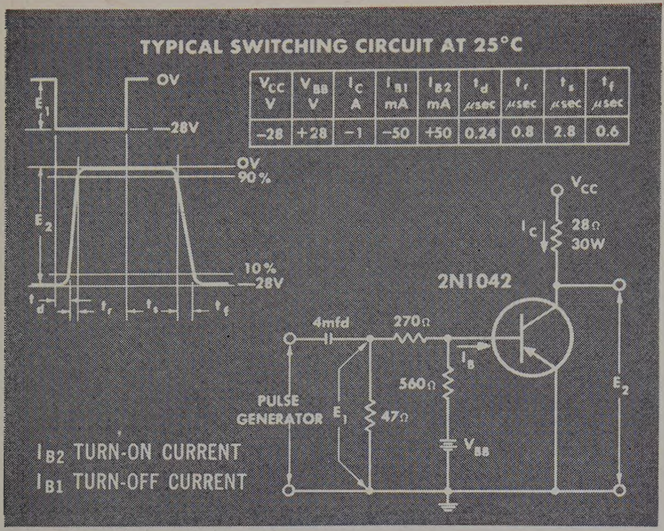
nization in Transistor Production

Transistor Characterization at VHF

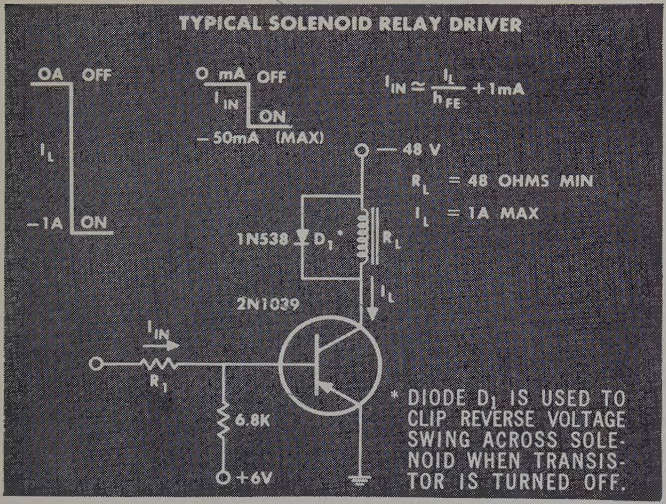
A Glass Transistor Enclosure

Transistor Thermal Stability

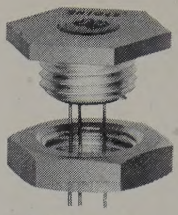
INDUSTRY'S BROADEST LINE O



V_{CC} V	V_{BB} V	I_C A	I_{B1} mA	I_{B2} mA	t_d µsec	t_r µsec	t_s µsec	t_f µsec
−28	+28	−1	−50	+50	0.24	0.8	2.8	0.6



NEW POWER SWITCHINC TRANSISTORS



(ACTUAL SIZE)

NEW P-N-P germanium powe switching transistors *guarantee* 5.5 W dissipation at 25°C with voltage rat ings of 40, 60, 80, and 100 volts fo optimum design flexibility. The func tional design of the heat sink assure rapid installation requiring only on mounting hole through the chassis You get *guaranteed* 20-to-60 beta spread and a low 0.16 ohm saturation resistance at the 3A maximum collecto rating. In addition, a maximum 125 µA collector revers current is *guaranteed* at one-half rated breakdown volt tage with TI 2N1042, 2N1043, 2N1044, and 2N104 alloy junction transistors.

These new devices are well suited for your switchin circuits . . . relay drivers . . . audio and pulse amplifiers

NEW MEDIUM POWEF SWITCHING TRANSISTORS

(ACTUAL SIZE)

NEW P-N-P germanium mediun power transistors give you switchin times as low as 1.1 µsec. TI 2N103 2N1039, 2N1040, and 2N1041 allo junction transistors provide 800 mW dissipation in free air at 25°C, 450 mW at 55°C . . . with voltage ratings of 40, 60, 80, and 100 volts In addition, *guaranteed* 20-to-60 beta spread and lov 0.2 ohm saturation resistance assure reliable perform ance for your high speed switching circuits . . . rela drivers . . . low power audio and pulse amplifiers.

		Type	Dissipation at 25°C	Collector Voltage-V max	Collector Current A max	Beta min	Beta max	Collector Reverse Current I_{co} max µA	V	Saturation Resistance Ohm
computer power	pnp	2N1046	15W	−80	−3	40	70 (Avg)	−1mA	−40	0.75
medium power		2N1038	800mW	−40	−1	20	60	−125	−20	0.2
	pnp	2N1039	800mW	−60	−1	20	60	−125	−30	0.2
		2N1040	800mW	−80	−1	20	60	−125	−40	0.2
		2N1041	800mW	−100	−1	20	60	−125	−50	0.2
power		2N456	50W	−40	−5	30@5A avg.		−2mA	−40	0.048
	pnp	2N457	50W	−60	−5	30@5A avg.		−2mA	−60	0.048
		2N458	50W	−80	−5	30@5A avg.		−2mA	−80	0.048
		2N1021	50W	−100	−5	23@5A avg.		−2mA	−100	0.08
		2N1022	50W	−120	−5	23@5A avg.		−2mA	−120	0.08
		2N1042	5.5W	−40	−3	20	60	−125	−20	0.16
		2N1043	5.5W	−60	−3	20	60	−125	−30	0.16
		2N1044	5.5W	−80	−3	20	60	−125	−40	0.16
		2N1045	5.5W	−100	−3	20	60	−125	−50	0.16

IMMEDIATELY AVAILABLE IN PRODUCTION QUANTITIES OF

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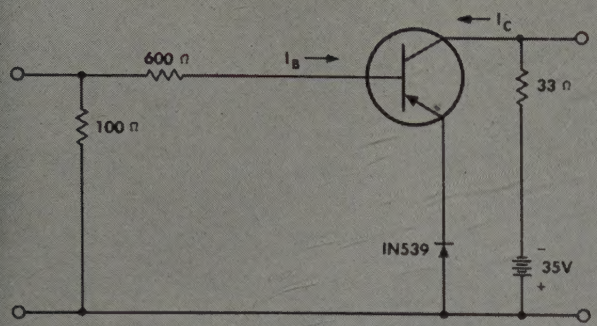
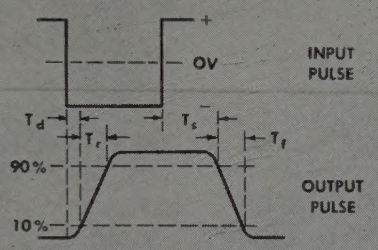
ERMANIUM POWER TRANSISTORS!

TYPICAL SWITCHING CHARACTERISTICS



TYPICAL SWITCHING TIMES

T_d	Delay Time	0.3	μsec
T_r	Rise Time	0.7	μsec
T_s	Storage Time	1.2	μsec
T_f	Fall Time	0.5	μsec



TEST CURRENTS

I_{B1} (Turn-on Current) = – 30mA

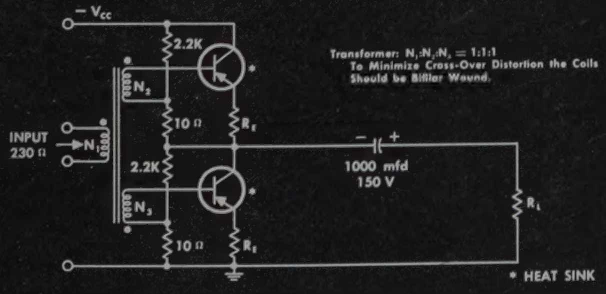
I_{B2} (Turn-off Current) = + 30mA

I_C (Collector Current) = – 1A

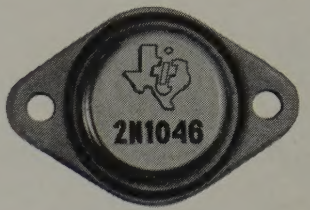
TYPICAL 20 WATT AMPLIFIER

POWER GAIN = 23 db

TRANSISTOR	V_{CC} V	R_L Ω	EFFICIENCY	DISTORTION 20 WATTS	R_E Ω
2N1021	–80	30	66%	2%	3
2N1022	–100	50	66%	2%	5



NEW HIGHEST FREQUENCY COMPUTER POWER TRANSISTOR



(ACTUAL SIZE)

NEW TI 2N1046 combines *high power, high frequency* and *high voltage* performance in a single transistor package! This P-N-P diffused base germanium transistor has *guaranteed* dissipation to 15 watts and collector breakdown voltage to 80 volts with 12 mc typical alpha cutoff. Extremely low collector reverse current averaging 0.2 ma at 40 volts and a low 0.75 ohm saturation resistance assure reliable operating characteristics.

Designed for your deflection circuits and computer core driving applications, the 2N1046 has a typical 10mc internal cutoff frequency, f_T (point at which forward current transfer ratio equals unity).

NEW HIGHEST VOLTAGE TRANSISTORS

(ACTUAL SIZE)

NEW TI 2N1021 and 2N1022 germanium transistors, *with maximum operating voltages of 100 V and 120 V respectively,* provide typical betas of 70 at 1A . . . 23 at 5A!

You get *guaranteed* 700 μA maximum collector reverse current at one-half rated voltage and 2mA maximum at full rated voltage in addition to extremely low saturation resistance . . . 0.08 ohm R_{CS}.

For your audio, servo and power applications, consider these outstanding performance characteristics and specify TI germanium transistors.

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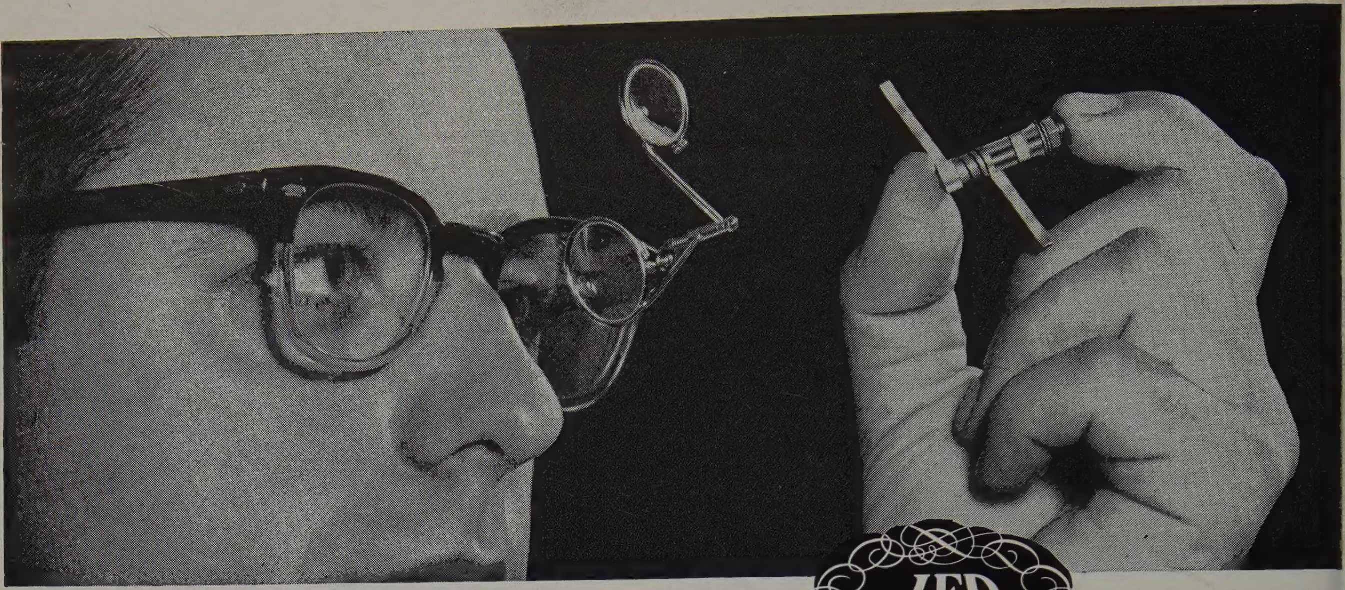

NEW FROM JFD Electronics

LC TUNERS

Why use *two*—a capacitor and inductor—when *one* will do? The new JFD LC Tuner combines a variable inductor *and* capacitor in one compact unit. For space-conscious design engineers this means more circuit in less space, better reliability, greater economy, faster assembly, reduced size and weight.

A few of the many advantages of JFD LC Tuners are:

1. Rugged electro-mechanical construction affords unusually high stability under conditions of severe shock and vibration.

2. Use of glass or quartz dielectric assures a low temperature coefficient and operation without derating over a wide range of extreme environmental conditions.

3. Sensitive adjustment with anti-backlash design for smooth and positive tuning.

4. Flexibility in design to suit circuit requirements. The number of turns, types of windings, size and type of capacitor plates, Q and other parameters can be designed to suit individual circuit requirements. Performance characteristics can also be varied by using other core materials, such as, brass or ferrites, by having the piston grounded or ungrounded and by other types of loading.

This is another example of JFD creative engineering to solve today's problems and tomorrow's applications. For information or engineering assistance on your specific tuning needs, call or write today.

Panel and Printed Circuit Mounting Types Standard LC Tuners Now Available

Model	Self Resonating Frequency Range	Length Above Panel	Diameter
LC303	450–700 MC	.635	5/16"
LC304	300–500 MC	.845	5/16"
LC306	200–450 MC	1.104	5/16"
LC309	125–200 MC	1.691	5/16"

PHONE DEWEY 1-1000

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ONLY RAYTHEON OFFERS BOTH SILICON TRANSISTORS

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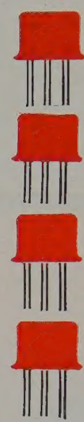
for COMPLEMENTARY CIRCUITS

because characteristics are so similar as to permit full and confident use

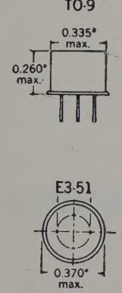

Actual Size

Specify RAYTHEON and get these significant advantages:

- Higher, more constant beta
- Lower saturation voltage
- Low noise type available in both PNP and NPN
- Made by the Raytheon reliable fusion alloy process which assures more constant characteristics over the entire temperature range

FOR LARGE SIGNAL APPLICATIONS

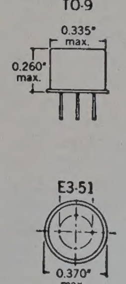
Temperature Range −65°C to +160°C

		Type	I_{EO} or I_{CO} at V_{CB} = 20 V_{dc} µA	V_{CE} max. volts	H_{FE}† ave.	r_b' f = 1Mc ohms	r_c kilohms	Noise Figure db (max.)	C_{ob} f = 100Kc ave. µµf	$f_{\alpha b}$ ave. Kc
TO-9  E3-51	PNP	2N327A	0.005	−40	15	1200	500	30	65	200
		2N328A	0.005	−35	30	1400	500	30	65	300
		2N329A	0.005	−30	60	1500	500	30	65	400
		2N330A	0.005	−30	25	1300	500	15	65	250
	NPN	2N619	0.005	50	15	2000	500	30	35	200
		2N620	0.005	40	30	2500	500	30	35	350
		2N621	0.005	30	60	2700	500	30	35	500
		2N622	0.005	30	25	2400	500	15	35	300

†for PNP, I_B = −0.1mA; V_{CE} = −0.5V; for NPN, I_B = 0.5mA; V_{CE} = 1.5V

FOR SMALL SIGNAL APPLICATIONS

Temperature Range −65°C to +160°C

		Type	I_{EO} or I_{CO} at V_{CB} = 20 V_{dc} µA	V_{CE} max. volts	h_{fe}* ave.	h_{ie}* max. ohms	h_{oe}* max. µmhos	Noise* Figure db	C_{ob} f = 100Kc ave. µµf	$f_{\alpha b}$ ave. Kc
TO-9  E3-51	PNP	2N1034	0.005	−40	15	3000	70	30	65	200
		2N1035	0.005	−35	30	3000	85	30	65	300
		2N1036	0.005	−30	60	3000	100	30	65	400
		2N1037	0.005	−35	30	3000	85	15	65	250
	NPN	2N1074	0.005	50	15	3500	70	30	35	200
		2N1075	0.005	40	30	3500	85	30	35	350
		2N1076	0.005	30	60	3500	100	30	35	500
		2N1077	0.005	30	25	3500	85	15	35	300

*V_C = 5V; I_E = 3mA

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SEMICONDUCTOR PRODUCTS

SANFORD R. COWAN, Publisher

January 1959 Vol. 2, No. 1

Front Cover

The photograph shown represents definite progress in a problem area of the semiconductor industry—mechanization. It is effectively a "merry-go-round," designed and built at Texas Instruments Inc., which speeds the production of grown junction germanium transistors. The operator at rear loads an unformed header into the carriers on the wheel. The machine then trims the internal leads of the header and bends them to accept the transistor bar. Paste solder is mechanically applied just before the header reaches the second operator, who places the transistor bar onto the solder. The transistor is moved into a hot furnace which hardens the solder. The holders then move the transistors through an etch, a wash and into a drying oven. As they move out of the oven, they are ejected before the first operator.

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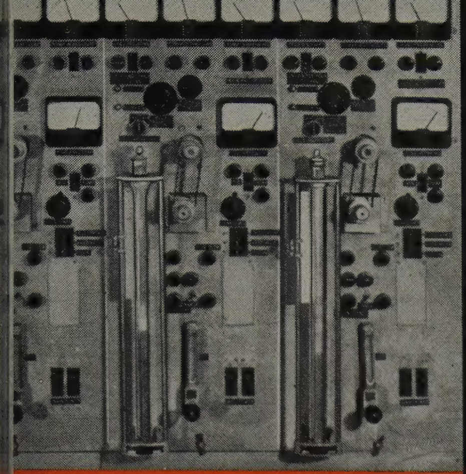
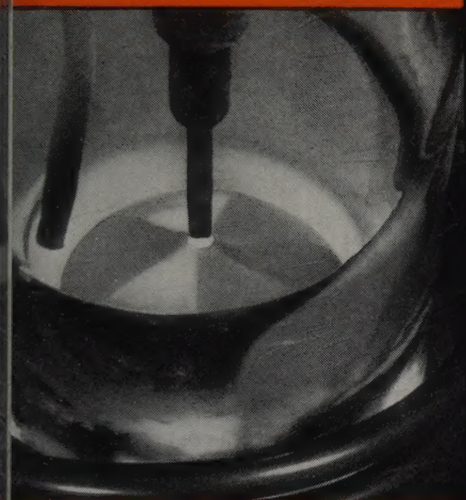


oa's unique automated process assures ict uniformity.



l cleanliness test requires three-sixteenths clearance between test crystal and crucible.

TRANCOA SILICON... *Key to increased yields!*

Multiple Zone Refining of every lot permits accurate boron content measurement.

Three characterization crystals are grown from each lot — one for resistivity, type and lifetime determination; another for cleanliness; a third for boron content.

Higher quality silicon can improve your semiconductor device yields. *Trancoa* offers this higher quality at no increase in price!

Grade for grade, the superior quality of Trancoa Silicon is assured by our unique process and exacting specifications. In addition to the standard tests for resistivity, lifetime and base boron level — every lot of Trancoa Silicon must also meet two other important requirements:

Cleanliness — the vital factor directly affecting your crystal yield! Trancoa specifications require that a doped single crystal be drawn with only three-sixteenths of an inch clearance between crystal and crucible. Any fuming, dross, or wetting of the quartz is cause for internal rejection.

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This combination of a new improved process plus added quality standards assures you of receiving better silicon, thus better yields, at no increase in cost.

PRODUCT SPECIFICATIONS

Grade	Resistivity P-Type	Resistivity N-Type	Max. Resistivity Ratio for 10% & 60% Points	Max. Boron Content (ppb)
IA	500	250	3:1	0.5
I	100	50	3:1	0.5
II	50	20	3:1	1.0
III	25	10	3:1	2.0
IV	2.5	1.0	3:1	4.0

For complete information write for brochure, *Trancoa Methods for Evaluating Silicon*, Trancoa Chemical Corporation, Dept. E-1, 312-326 Ash Street, Reading, Massachusetts.

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Editorial . . .

With deep regret we advise our readers that Mrs. Carolyn Binderman, Assistant Circulation Manager, passed away December 4th after a long illness.

pecial Announcement

Beginning with the February, 1959 issue a new eader service facility will be made available to readrs and advertisers.

arametric Devices

In the past two years parametric devices have reeived great attention for application to high frequency, low noise amplifiers. The principle of operaion is based on the fact that, if a periodic signal of requency f is fed to a resonant circuit, power amplifiation may be obtained by varying periodically one of he reactances of the circuit at frequency $2f$. In order hat stable and noise-free amplification may be obained, it is necessary that suitable means of uniateralization be introduced in the device. Various chemes have been developed in leading U.S. laboraories.

An additional simple application of the parametric rinciple has been made recently in Japan in connecion with switching circuits. It is found that for a ixed excitation frequency ($2f$), the phase of the f-ignal can acquire one of two stable values, differing y π. Hence, with reference to such phase, the paranetric device constitutes a bistable element and may be used to build computing blocks for the fundamental operations of "and," "or" and "not." The device (called "parametron" by its inventor E. Goto) utilizes a couple of ferrite cores with two series windings for the excitation frequency and two counter-series windings for the f-signal circuit. The latter circuit is completed with a resonating capacitor. Because of the signal appears in the resonant circuit. The excitation balance obtained, no component of the excitation circuit is fed with a current containing a *d-c* component as well as a component at frequency $2f$. When a signal at frequency f is fed into the resonant circuit, this becomes synchronized on one or the other of the phases. Building blocks are obtained feeding three of such devices into a fourth one. If one of the three devices is kept at fixed operating phase, and the other two accept two separate signals, the phase of the resulting oscillation in the fourth device may be controlled to provide digital operations of "and," "or" or "not." Although in the present realization no active devices are utilized, it is entirely possible that applications of the same principle to semiconductor devices would provide faster and improved operation.

SEASON'S GREETINGS!

Samuel L. Marshall

SEMICONDUCTOR CIRCUIT DESIGN AWARDS RULES

. Articles and nomographs published in Semiconductor products between April 1959 and March 1960 inclusive will be considered eligible for the awards. It is therefore advisable to submit manuscripts as soon as possible.

. Mail manuscripts to Semiconductor Products Magazine, 300 W. 43rd St., New York 36, N.Y. Attention: S. L. Marshall, Editor.

Prizes will be 1) an engraved gold medal and $500.00 for the most outstanding Semiconductor Circuit Design Article, and 2) an engraved gold medal and $500.00 for the most outstanding Nomograph relating to Semiconductor Circuit Design.

. Manuscripts are limited to 3,000 words or less, exclusive of illustrations and diagrams. Manuscripts should be typed double-spaced, and submitted in duplicate. Illustrations and diagrams need not be inked or ruled; however they must be neatly prepared and legible.

5. Judges' decision shall be final, and authors agree to accept these decisions as a condition of entry. Semiconductor Products reserves the right to correct typographical errors that may appear inadvertently in the manuscript.

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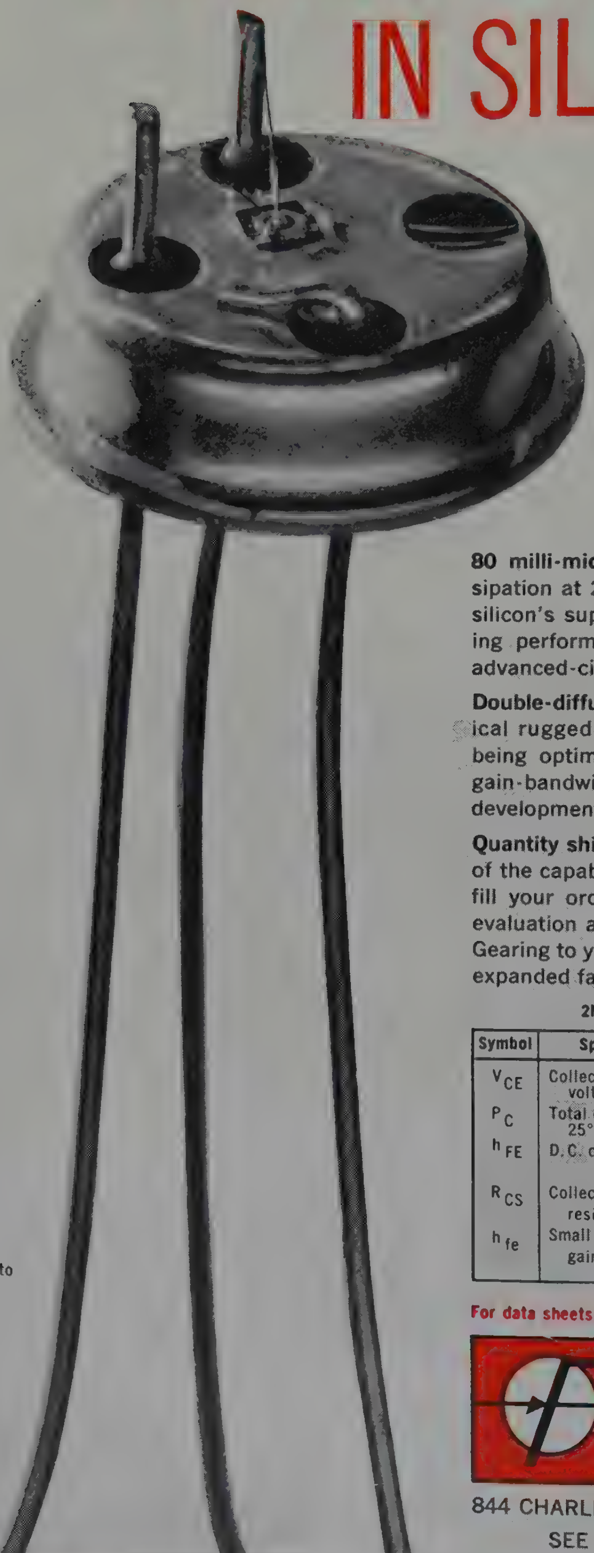
INDEX OF AUTHORS

FROM FAIRCHILD

MESA TRANSISTORS IN SILICON



Greatly enlarged photo of Fairchild 2N696 before capping

80 milli-micro-second rise time with 2 watts power dissipation at 25° C. This speed and power is combined with silicon's superior high-temperature reliability. The switching performance that this affords has a place in every advanced-circuit evaluation program.

Double-diffused mesa-type construction provides mechanical ruggedness and excellent heat dissipation besides being optimum for high-frequency performance (typical gain-bandwidth product 80 Mc). This type is under intense development everywhere. Fairchild has it in production.

Quantity shipments now being made give conclusive proof of the capabilities of Fairchild's staff and facilities. We can fill your orders promptly. You can start immediately on evaluation and building of complete prototype equipment. Gearing to your future production needs, Fairchild will have expanded facilities to over 80,000 square feet by early '59.

2N696 and 2N697 — NPN SILICON TRANSISTORS

Symbol	Specification	Rating	Characteristics	Test Conditions
V_{CE}	Collector to Emitter voltage (25° C.)	40v		
P_C	Total dissipation at 25° C. Case temp.	2 watts		
h_{FE}	D.C. current gain		2N696 – 20-60 2N697 – 40-120	I_C – 150ma V_C – 10v
R_{CS}	Collector saturation resistance		6Ω typical 10Ω max.	I_C – 150ma I_B – 15ma
h_{fe}	Small signal current gain at f=20Mc		4 typical	I_C – 50ma V_C – 10v

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Transistor Characterization at VHF

R. P. ABRAHAM* and R. J. KIRKPATRICK*

PART 1

This article describes a technique for the characterization of transistors in the common emitter configuration at very high frequencies (30-300 *mc*). The characterization consists of four measurements and subsequent calculations which yield the four complex hybrid parameters; the hybrid parameters may then be used to find the validity as well as the element values of any equivalent circuit. The measurements which are made are (1) insertion voltage gain, (2) input impedance with a load of 50 ohms, (3) h_{22}, and (4) y_{22}. In the VHF region transmission line techniques become necessary; thus, coaxial jigs have been designed to provide the transition between the transistor and the coaxial line as well as to accommodate the bias circuitry. These jigs in conjunction with a Rhode-Schwartz Diagraph provide the necessary measurement equipment. The calculations needed to transform the measured data to the hybrid parameters are programmed on a digital computer. These calculations also take account of the small imperfections in the jigs. Typical data on the diffused base type of transistor is presented. These data are shown to be in good agreement with the calculated performance of a tee equivalent circuit.

I. INTRODUCTION

THIS ARTICLE describes a method for obtaining the hybrid parameters of a transistor in the common emitter connection over a frequency range of 30 to 300 *mc*. The purposes of the high frequency transistor measurements are to confirm an equivalent circuit of the transistor and to evaluate its parameters. The design of active networks using transistors depends to a large extent on these accurate evaluations. The measurements necessary to obtain the four pole parameters are as follows:

1. h_{11}, short circuit input impedance
2. h_{22}, open circuit output admittance
3. y_{22}, short circuit output admittance
4. Insertion voltage gain

From these measurements h_{21} and h_{12} can be calculated. A Rhode-Schwarz Diagraph in conjunction with specially designed coaxial jigs is used to obtain the required measurements.

Section II of the article describes the method of measurement and the equipment involved. Section III describes in detail the construction of the coaxial jigs and the biasing arrangement. Section IV contains the evaluation of the coaxial jigs; Section V gives the theoretical hybrid parameters for a tee equivalent circuit; Section VI shows the calculations necessary to obtain the hybrid parameters; and Section VII presents sample data and compares this data with the equivalent circuit. Sections VI and VII will appear in the concluding installment.

*Bell Telephone Laboratories, Inc.
Murray Hill, New Jersey.

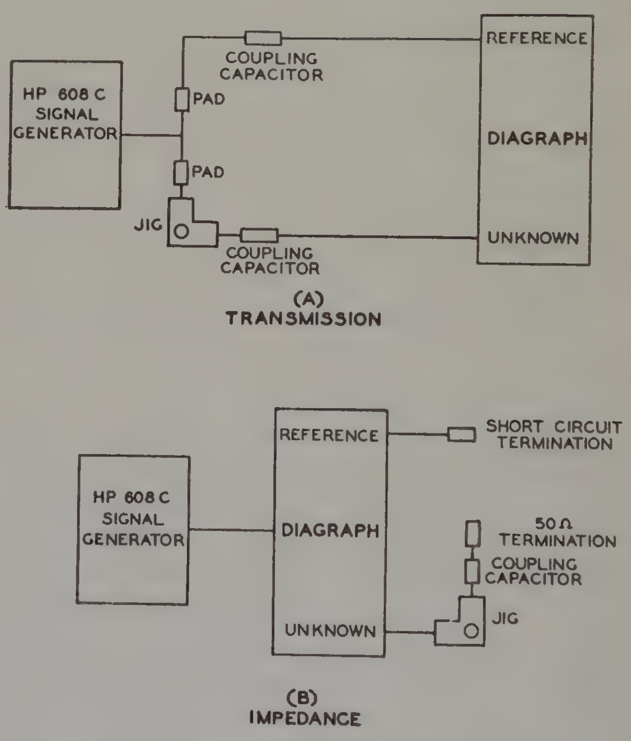


Fig. 1 Measurement block diagrams.

II. MEASUREMENT TECHNIQUES

Diagraph—Theory of Operation

The Rhode-Schwarz Diagraph is an instrument capable of measuring (1) complex reflection coefficient and (2) transmission. Two matched directional couplers sample the signals in both the reference and

unknown channels; the directional couplers are sensitive only to the waves traveling in one direction. The output from each coupler is converted to an *i-f* frequency of 10 *mc* by being mixed with the signal from a local oscillator. A special automatic frequency control circuit makes the local oscillator follow any variations of the signal generator frequency so that frequency deviation errors are largely eliminated. The two 10 *mc* *i-f* amplifiers have a broadband characteristic (approximately 70 *kc*) to insure a flat phase response. The magnitude of the detected signal in the reference channel is indicated on a front panel meter marked "Reference Voltage." The magnitude of the unknown signal is displayed on a circular translucent chart by means of a calibrated light spot galvanometer; the distance from this light spot to the center of the chart is proportional to the signal strength in the unknown channel. In order to measure the complex wave relationship it is also necessary to measure the phase angle between the two signals. To accomplish this the output signals of the two *i-f* amplifiers are applied to opposite ends of a circular delay line. Since this line is slightly longer than 180 electrical degrees at the *i-f* frequency, a null will exist at the point on the line where the two signals cancel. The location of this null is determined by the relative phase of the two signals; it will be displaced from the end of the line by an amount proportional to one-half the phase angle between the two signals. A capacitive probe geared 2:1 to the translucent chart may be rotated along the entire length of the line to determine the location of the null. Thus, there is indicated on the chart a vector whose length and angle are proportional to the magnitude and phase angle of the desired complex wave relationships.

Diagraph Immittance Measurements

When the Diagraph is used as an immittance measuring device, the test signal power at the desired frequency is divided equally between the unknown and reference lines; 40 *db* of padding in each provides isolation between the two lines. A short circuit is connected to the reference terminal and the unknown immittance is connected to the unknown terminal. Since the directional couplers are sensitive to the reflected signals, the complex wave relationship determines the unknown reflection coefficient. To read the immittance value directly, a Smith chart or a Carter chart is placed in the transparent chart holder. The charts are made of a translucent material and are suitable for marking with a pencil. To make the immittance measurement independent of losses or phase shift in the cable connecting the unknown impedance to the instrument, identical lengths of cable are connected to the reference and unknown jacks. By putting the short circuit at the far end of the reference cable, the reference plane is moved from the Diagraph to the terminals of the unknown immittance.

Listed below are the specifications of the Diagraph when it is used as an immittance measuring set.

Characteristic impedance	— 50 ohms
Measuring range	— 1-2500 ohms
Accuracy	— ± (3% ± 0.02) of the reflection coefficient

Diagraph Transmission Measurements

For the measurement of the transmission characteristics of four terminal networks the input and output signals are compared directly. The Diagraph operates as before comparing the magnitude and phase of two traveling waves; the signal power is divided external to the Diagraph by means of a coaxial tee and two isolating pads. Half of the signal power is fed to the reference line and the other half to the input of the network; the output of this network is then fed to the unknown line. Thus, with the transmission chart placed in the chart holder, readings of attenuation in decibels and phase shift in degrees are obtained directly.

Listed below are the specifications of the Diagraph when used as a transmission measuring set.

Measuring range	
Attenuation	— 0 to 30 *db*
Phase	— 0 to 360°
Accuracy	
Attenuation	— ± 5% ± 0.2 *db*
Phase at 0 *db*	— ± 1.5°
at 20 *db*	— ± 5°
Nominal input impedance	— 50 ohms

Measurement of the h_{11} Parameter

Figure 1B shows the block diagram for determining h_{11}. The h_{11} parameter is obtained from the input impedance measurements with the output terminated in 50 ohms. As previously described in the Diagraph immittance measurements, two lengths of cable are used; one cable connects the h_{11}-h_{21} jig to the unknown terminal of the Diagraph. The other cable connects the reference jack of the instrument to a shorted line whose length is the same as the distance from the input end of the h_{11}-h_{21} jig to the transistor socket. With the transistor biased at the desired operating point and a Smith chart in the chart holder, a direct measurement of the input impedance of the transistor is obtained. The h_{11} parameter is defined as the short circuit input impedance, and the measured transistor is terminated in 50 ohms; thus, a small termination error exists and is discussed in Section VI of this article.

Measurement of the h_{22} Parameter

The h_{22} parameter is measured in the same way as the h_{11} parameter as far as the measuring arrangement is concerned (the Smith Chart is reversed so that admittance can be read directly). Since the h_{22} parameter is defined as the open circuit output admit-

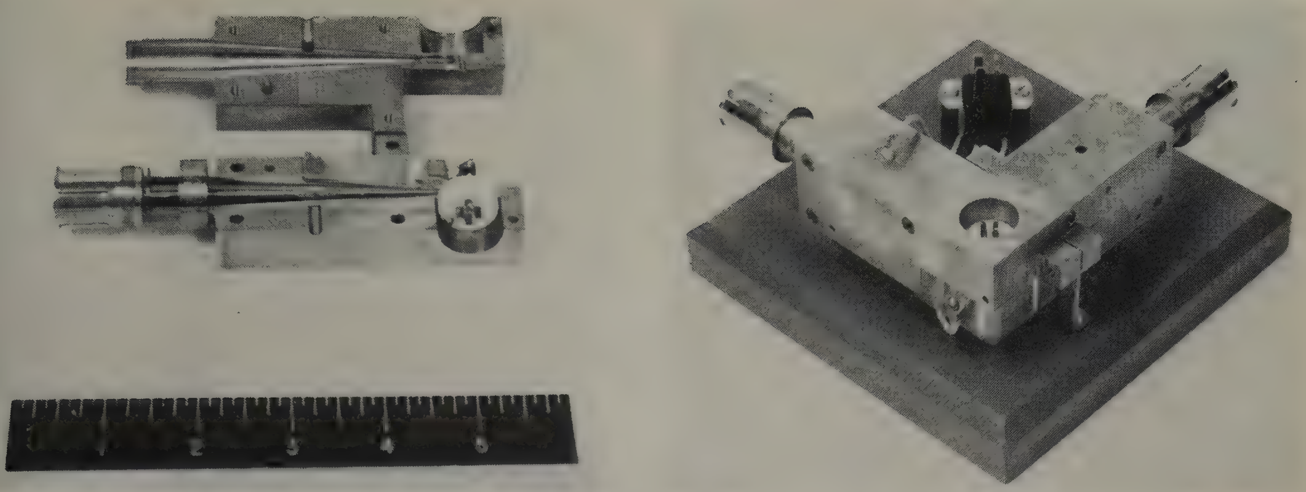


Fig. 2 Photograph of the h_{11}-h_{21} jig.

tance, the base connection of the h_{22}-y_{22} jig is *a-c* open circuited. The imperfection of this open circuit is taken into account in Section VI.

Measurement of the y_{22} Parameter

y_{22} is defined as the short circuit output admittance; hence an *a-c* short circuit between base and ground is provided by the h_{22}-y_{22} jig. An admittance measurement is then made in the same manner as the previously described h_{22} measurement.

Measurement of Insertion Voltage Gain

In order to determine the transistor current gain, h_{21}, an insertion voltage gain measurement is made utilizing the Diagraph and the h_{11}-h_{21} coaxial jig. The calculation of h_{21} from the insertion gain including the appropriate modifications of h_{11} and h_{22} is given in Section VI. *Fig. 1A* shows the block diagram for making insertion voltage gain measurements. As mentioned previously, a signal is fed from a generator into a coaxial tee; one-half of the signal power is fed through an isolating pad into the h_{11}-h_{21} jig (to the transistor under test); the output of the h_{11}-h_{21} jig is then fed to the unknown terminal of the Diagraph. The other half of the signal power is fed through a similar isolating pad into a line, equal in length to the h_{11}-h_{21} jig, which in turn feeds the reference jack of the Diagraph. Because the transistor under test is not driven by a constant current source, the h_{11} measurement is an important factor in the calculation of the h_{21} parameter.

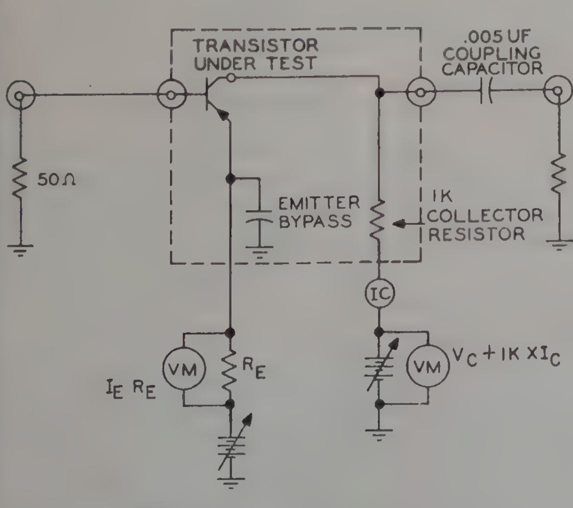


Fig. 3 Schematic diagram for the h_{11}-h_{21} jig.

III. DESCRIPTION AND CONSTRUCTION OF THE COAXIAL JIGS

Construction of the h_{11}-h_{21} Jig (See Fig. 2)

The frequency range from 30 to 300 *mc* represents a border region in that it is a transition range from lumped elements to distributed elements; thus, the coaxial jigs constitute a departure from lumped element design. The circuit diagram of the h_{11}-h_{21} jig is shown in *Fig. 3;* a common emitter configuration is employed which operates into an *a-c* coupled 50 ohm load. In the h_{11} measurement the 50 ohm value is presented by a coaxial 50 ohm termination; for the insertion voltage gain measurement, the 50 ohm load is the Diagraph input impedance. The overall assembly and construction are shown in *Fig. 4.* Each arm of this "ell" shaped jig is made from two blocks of brass tightly fastened together. The two blocks are machined as a unit to form the outer conductor of a tapered 50 ohm coaxial line. The center conductor of the coaxial line is also tapered to maintain a constant characteristic impedance.

The small end of the taper terminates at the transistor socket; this arrangement maintains a 50 ohm coaxial line as close as possible to the transistor being measured. The emitter bypass capacitor shown in *Fig. 4* is sandwiched between the two halves of each arm so that the edge is flush with the tapered outer conductor. By placing the capacitor in this position

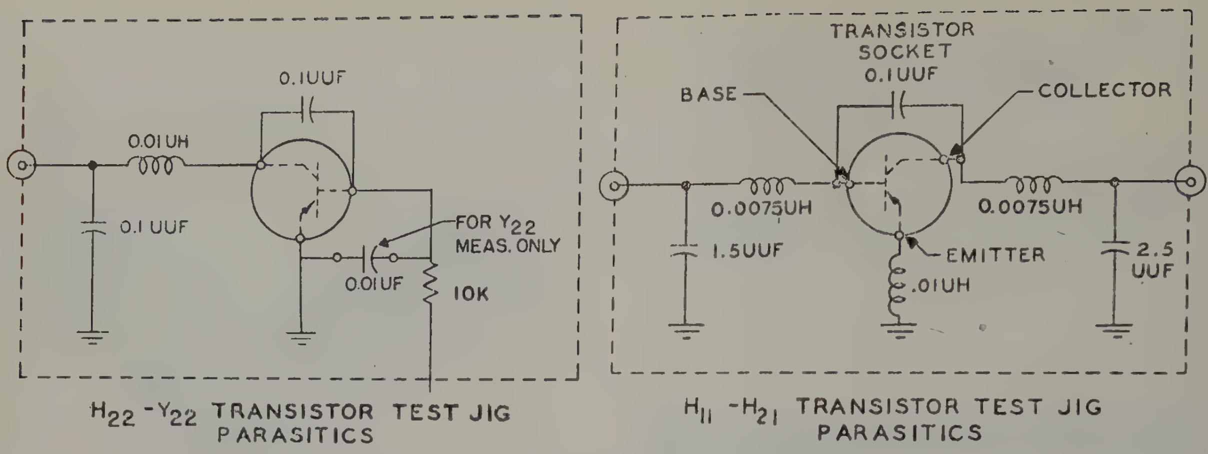


Fig. 5 Schematic diagram for jig parasitics.

the resulting transition from coaxial to two-wire (the transistor) is accomplished smoothly and the equivalent inductance in the emitter lead is a minimum. The high side of the capacitor, which is made up of sheets of silvered mica, is connected to the emitter pin of the socket. The outside of the outermost sheets is clamped tightly against the brass block and is at ground potential, as is every other sheet, by virtue of interleaved foil connecting them. The capacity of 0.002 μf brings the reactance of the capacitor to about 1 ohm in the lowest frequency range of interest, yet the emitter is isolated from *d-c* ground.

A 1K resistor, which supplies the collector bias, is fastened to the center conductor of the collector arm of the ell and is brought through a hole drilled in the block. The resistor has a negligible effect on the measurements as the *a-c* collector load is 50 ohms. A coaxial coupling capacitor (0.005 μf) is used to provide *d-c* isolation between the collector bias circuit and the 50 ohm load. The base connection is returned to ground through a 50 ohm pad or through the input impedance of the Diagraph.

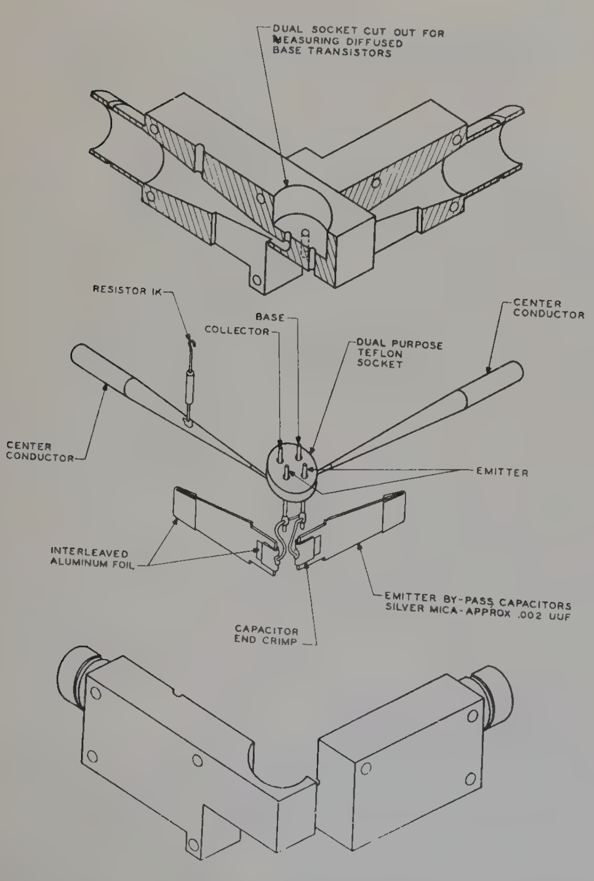


Fig. 4 Construction of the h_{11}-h_{21} jig.

Description of the h_{22}-y_{22} Jig

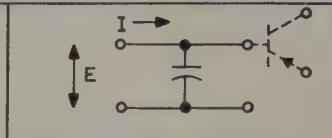
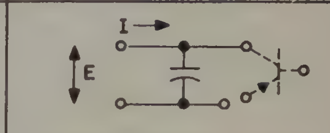
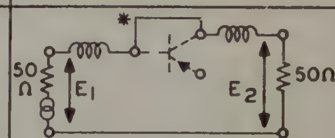
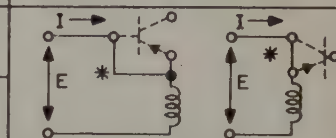
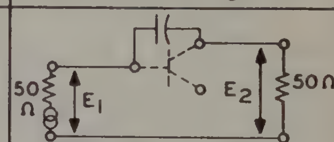
The h_{22}-y_{22} jig is a single collector arm of the previously described ell shaped jig used for measuring input impedance and insertion voltage gain. In this jig the construction of the capacitor, the dimensions of the conductors, and the socket arrangement are the same as for the previously described jig. The 1K collector bias resistor is omitted, and the 50 ohm impedance of the Diagraph is used to supply the collector current. The h_{22} measurement is made with a 10K low shunt capacity resistor connected from base to ground. The y_{22} measurement is made with the base connected to ground through a 0.01 μf capacitor.

IV. JIG EVALUATION

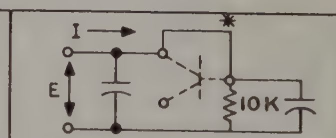
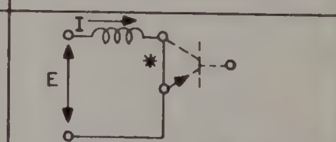
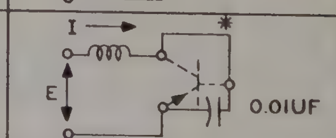
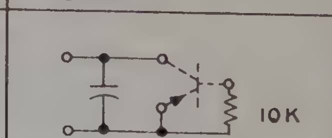
The main objective of the design of the coaxial jigs was to minimize the parasitics which would cause errors in the measurements. If the errors due to these parasitics are small, then they may be accurately accounted for by an appropriate calculation. The assumption is made that the parasitics can be represented by lumped elements, i.e., shunt capacity and lead inductance, which could be evaluated by simple open and short circuit measurements. The tests were made using the apparatus and circuit arrangement which are identical to the analogous transistor measurements. The open circuit measurements were taken with the socket vacant, and the short circuit tests were

TABLE I

H_{11}-H_{21} JIG

TEST NO.	PARASITICS MEASURED	MEASUREMENT MADE	SOCKET CONNECTIONS	RESULTS	TEST CONDITION & PARASITICS OF JIG * INDICATES SHORTING STRAP
1	INPUT CAPACITY	INPUT ADMITTANCE	SOCKET OPEN	1.5UUF	
2	OUTPUT CAPACITY	OUTPUT ADMITTANCE	SOCKET OPEN	2.5UUF	
3	INPUT INDUCTANCE	TRANSMISSION AND PHASE	BASE TO COLLECTOR SHORTED	0.0075 UH	
	OUTPUT INDUCTANCE			0.0075 UH	
4	EMITTER INDUCTANCE	OUTPUT IMPEDANCE	COLLECTOR TO EMITTER SHORT	0.0172 UH	
		INPUT IMPEDANCE	BASE TO EMITTER SHORT	0.0140UH	
5	INPUT TO OUTPUT COUPLING	TRANSMISSION AND PHASE	SOCKET OPEN	0.1UUF	

H_{22}-Y_{22} JIG

1	TOTAL SHUNT CAPACITY	OUTPUT ADMITTANCE	COLLECTOR TO BASE SHORTED	0.1UUF	
2	OUTPUT INDUCTANCE H_{22}	OUTPUT IMPEDANCE	COLLECTOR TO EMITTER SHORTED	0.01UH	
3	OUTPUT INDUCTANCE Y_{22}	OUTPUT IMPEDANCE	BASE TO COLLECTOR SHORTED	0.0075UH	
4	INPUT CAPACITY	INPUT ADMITTANCE	SOCKET OPEN	0.1UUF	

made by connecting a #18 wire of minimum length between the appropriate socket terminals; thus the socket and jig parasitics were evaluated. Table I shows the measurements taken on the h_{11}-h_{21} jig and the h_{22}-y_{22} jig, respectively; *Fig.* 5 shows the equivalent circuit for each of the jigs.

V. THEORETICAL HYBRID PARAMETERS

It would be extremely convenient if a low frequency equivalent circuit could be extended to accurately describe the action of transistors in the *vhf* region. It is shown in the following that the diffused base transistor allows this extension. The tee equiva-

lent circuit shown in *Fig. 6* is used to characterize the transistors which were measured. The common emitter hybrid parameters calculated from this equivalent circuit are compared with the measured hybrid parameters of a typical diffused base transistor. The so-called excess phase is taken into account by including an exponential term in the expression for "a."

h_{11}

The theoretical short circuit input impedance can be closely approximated by the circuit shown in *Fig. 7A*, and if the real part of h_{11} is plotted against the imaginary part, the circle diagram of *Fig. 7B* results.

h_{21}

The short circuit current gain obtained from the equivalent circuit is

$$h_{21} = \frac{a}{1-a} \tag{1}$$

when r'_c is neglected* and where

$$a = a_o \frac{e^{-jm\frac{f}{f_a}}}{1 + j\frac{f}{f_a}}$$

Computations were carried out with the aid of a digital computer for various values of a_o and m. *Fig. 8* shows a typical result where h_{21} is plotted as a function of f/f_a for $a_o = 0.98$ and $m = 0.6$. If the transport of minority carriers is effected by means of diffusion alone, $m = 0.2$; however, if any electric field[1] exists within the base region that assists the transport mechanism, m may exceed 0.2.

If $f \ll f_a/m$ then

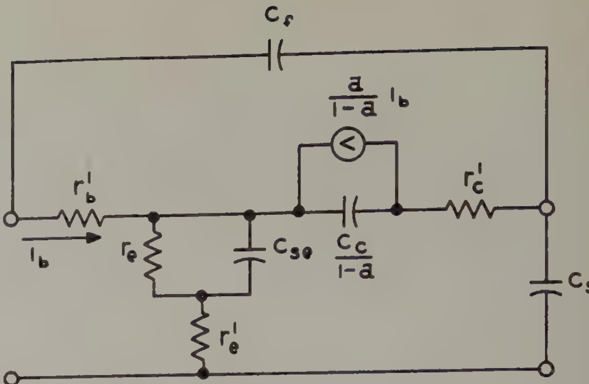
$$e^{-jm\frac{f}{f_a}} \approx 1 - jm\frac{f}{f_a} \tag{2}$$

By using this approximation in *only* the denominator of equation (1) the h_{21} parameter is approximately

$$h_{21} \approx \frac{a_o}{(1-a_o)} \cdot \frac{e^{-jm\frac{f}{f_a}}}{\left[1 + j\frac{f\,(1+a_o m)}{f_a\,(1-a_o)}\right]} \tag{3}$$

The frequency at which the common emitter short circuit current gain is unity is given approximately by

$$\approx \frac{f_a}{1 + a_o m} = f_{ae} \tag{4}$$



r'_c COLLECTOR BODY RESISTANCE
r'_b OHMIC BASE RESISTANCE
r_e EMITTER JUNCTION RESISTANCE
r'_e EMITTER CONTACT RESISTANCE
C_{se} EMITTER STORAGE CAPACITY
C_c COLLECTOR DEPLETION LAYER CAPACITY
C_f STRAY COLLECTOR TO BASE CAPACITY
C_s STRAY COLLECTOR TO GROUND CAPACITY

$$a = a_o \frac{e^{-jm\frac{f}{f_a}}}{1 + j\frac{f}{f_a}}$$

Fig. 6 Tee equivalent circuit.

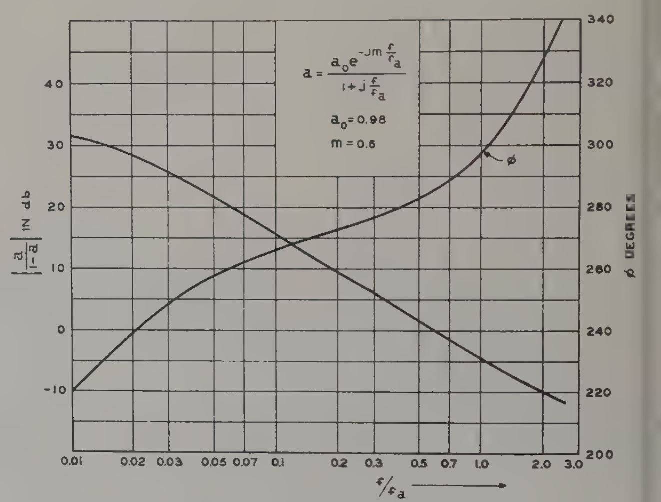


Fig. 8 Theoretical h_{21}.

h_{22}

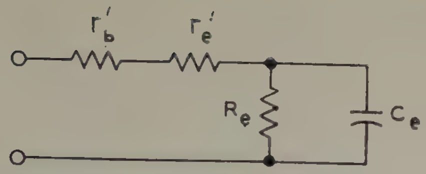
The open circuit output admittance derived from the tee equivalent circuit can be represented by the circuit of *Fig. 9*. The real and imaginary parts of h_{22} may be equated to a resistance and a capacitance in parallel. This resistance and capacitance are plotted versus frequency in *Fig. 9* where $(1\text{-}a)^{-1}$ was computed for $a_o = 0.97$, $m = 0.4$ and $f_a = 1000$ *mc*. The sum of collector capacity and the collector to base header capacity was assumed to be 1 μμf; C_s and r'_c were neglected.

h_{21}

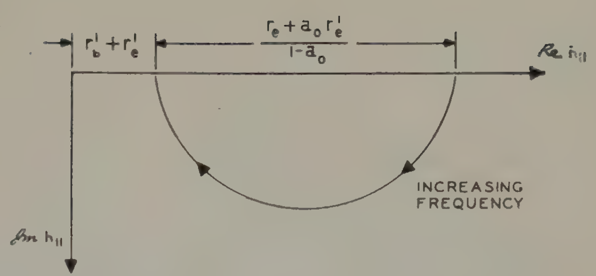
A straightforward analysis of the equivalent circuit shown in *Fig. 6* neglecting r'_e and r'_c and for fre-

*r'_c is usually small compared to normal load impedances and may be accounted for by adding r_c' in series with the load.

1. C. A. Lee, "A High-Frequency Diffused Base Germanium Transistor," Bell System Technical Journal, vol 35, Number 1, p. 23, January 1956.



(A)



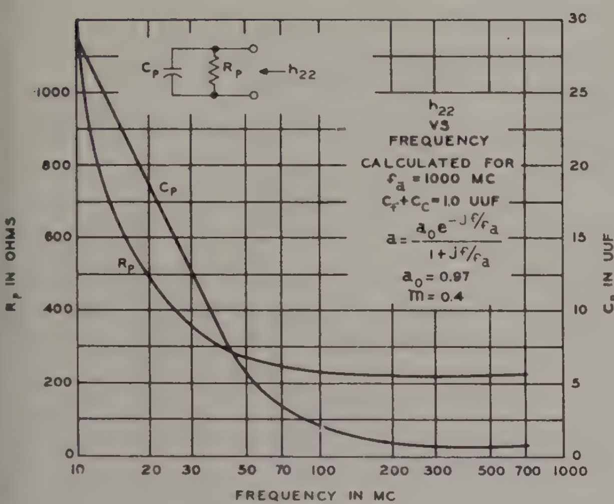
(B)

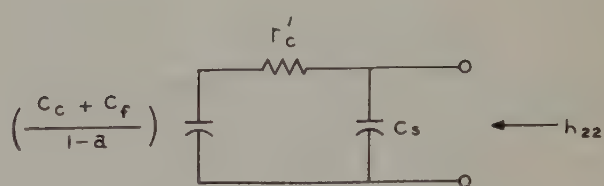
r'_b OHMIC BASE RESISTANCE
r'_e SERIES EMITTER RESISTANCE
r_e EMITTER JUNCTION RESISTANCE

$$R_e = \frac{r_e + a_o r'_e}{1 - a_o} \qquad C_e = \frac{1}{(r_e + a_o r'_e)\,\omega_{ae}}$$

ω_{ae} = RADIAN FREQUENCY AT WHICH THE COMMON EMITTER CURRENT GAIN IS UNITY

Fig. 7 Equivalent circuit for short circuit input impedance.





r'_c COLLECTOR BODY RESISTANCE
C_c COLLECTOR DEPLETION LAYER CAPACITY
C_f STRAY CAPACITY, COLLECTOR TO BASE
C_s STRAY CAPACITY, COLLECTOR TO GROUND

$$a = a_o \frac{e^{-jm\frac{f}{f_a}}}{1 + j\frac{f}{f_a}}$$

Fig. 9 Theoretical h_{22}.

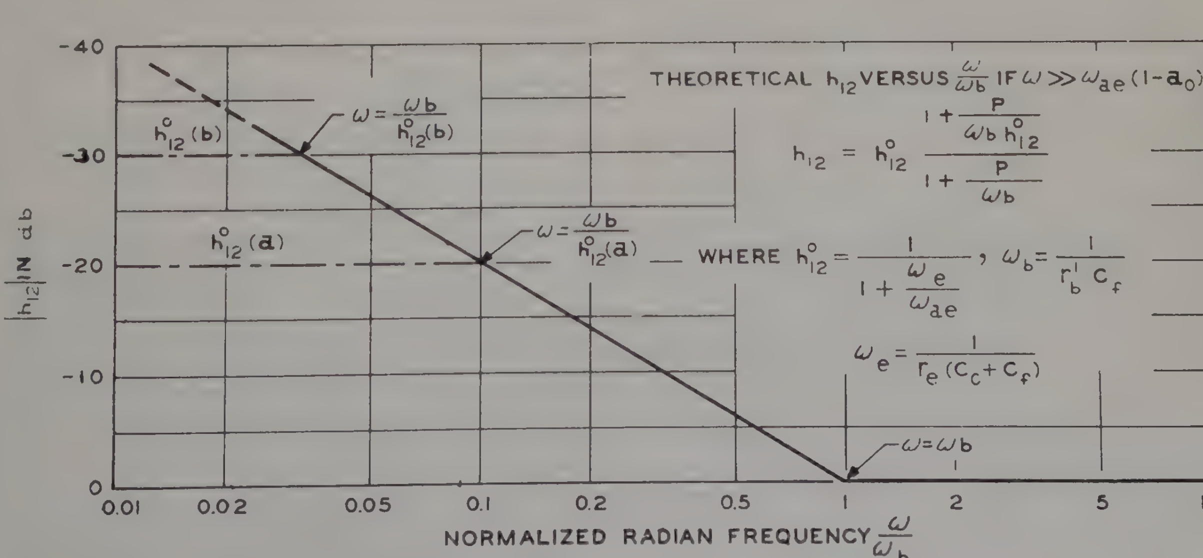


Fig. 10 Theoretical h_{12}.

quencies above the common emitter 3 *db* point $[f_{ae}(1\text{-}a_o)]$ gives

$$h_{12} \approx h^{\circ}_{12} \frac{\left(1 + \dfrac{p}{\omega_b\, h^{\circ}_{12}}\right)}{\left(1 + \dfrac{p}{\omega_b}\right)} \tag{5}$$

if $\omega_a \approx \omega_{ae}$ and

where $h^{\circ}_{12} = \dfrac{\omega_{ae}}{\omega_e}$, $\omega_e = \dfrac{1}{r_e\,(C_c + C_f)}$, and $\omega_b = \dfrac{1}{r_b C_f}$.

Appendix A gives a derivation of expression (5); plots of the asymptotic magnitude of h_{12} for two typical cases are shown in *Fig. 10.*

[TO BE CONCLUDED NEXT MONTH]

APPENDIX A

This appendix gives the derivation of the approximate expression for h_{12}. If r'_e and r'_c are neglected, a straight-forward nodal analysis of *Fig. 6* yields

$$h_{12} = \frac{Y_c + r_b C_f p \left[\dfrac{1}{r_b} + Y_c + Y_e\,(1-a)\right]}{Y_c + Y_e\,(1-a) + r_b C_f p \left[\dfrac{1}{r_b} + Y_c + Y_e\,(1-a)\right]} \tag{20}$$

where $Y_c = C_c p$, $Y_e = \frac{1}{r_e} + C_{se} p$, and p is complex frequency. If the emitter storage capacity can be approximated by $1/\omega_{ae} r_e$, then

$$Y_e = \frac{1 + \dfrac{p}{\omega_{ae}}}{r_e} \tag{21}$$

and using the approximation of (3)

$$(1-a) \approx (1-a_o) \frac{\left[1 + \dfrac{p}{\omega_{ae}\,(1-a_o)}\right]}{\left[1 + \dfrac{p}{\omega_a}\right]} \tag{22}$$

then

$$Y_e\,(1-a) \approx \frac{(1-a_o)}{r_e} \frac{\left[1 + \dfrac{p}{\omega_{ae}}\right]\left[1 + \dfrac{p}{\omega_{ae}\,(1-a_o)}\right]}{\left[1 + \dfrac{p}{\omega_a}\right]} \tag{23}$$

In the frequency range of interest, $\omega >> \omega_{ae}\,(1\text{-}a_o)$; hence

$$Y_e\,(1-a) \approx \frac{p}{r_e \omega_{ae}} \frac{\left[1 + \dfrac{p}{\omega_{ae}}\right]}{\left[1 + \dfrac{p}{\omega_a}\right]} \tag{24}$$

When m is small, $\omega_{ae} \approx \omega_a$; thus

$$Y_e\,(1-a) \approx \frac{p}{r_e \omega_{ae}} \tag{25}$$

Using expression (25) and $Y_c = C_c p$ equation (20) may be rewritten as

$$h_{12} \cong \frac{r_e\,(C_c + C_f)}{r_e\,(C_c + C_f) + \dfrac{1}{\omega_{ae}}} \; \frac{\left[1 + p\,\dfrac{r_e r_b C_f C_c + \dfrac{r_b C_f}{\omega_{ae}}}{r_e\,(C_c + C_f)}\right]}{\left[1 + p\,\dfrac{r_e r_b C_f C_c + \dfrac{r_b C_f}{\omega_{ae}}}{\dfrac{1}{\omega_{ae}} + r_e\,(C_c + C_f)}\right]} \tag{26}$$

With the following definitions

$$\omega_e = \frac{1}{r_e\,(C_c + C_f)}, \quad \omega_b = \frac{1}{r_b C_f}, \text{ and } \omega_o = \frac{1}{r_e C_c}$$

the above equation becomes

$$h_{12} \cong \frac{1}{1 + \dfrac{\omega_e}{\omega_{ae}}} \cdot \frac{1 + p\,\dfrac{\omega_e}{\omega_{ae}\omega_b}\left[1 + \dfrac{\omega_{ae}}{\omega_o}\right]}{1 + p\,\dfrac{\omega_e}{\omega_b}\left[\dfrac{1 + \dfrac{\omega_{ae}}{\omega_o}}{\omega_e + \omega_{ae}}\right]} \tag{27}$$

In most cases $\omega_o \gg \omega_{ae}$, $\omega_e \gg \omega_{ae}$; therefore,

$$h_{12} \cong \frac{\omega_{ae}}{\omega_e} \frac{\left(1 + \dfrac{p\omega_e}{\omega_b\, \omega_{ae}}\right)}{\left(1 + \dfrac{p}{\omega_b}\right)} \tag{28}$$

or

$$h_{12} = h^{\circ}_{12} \frac{1 + \dfrac{p}{\omega_b h^{\circ}_{12}}}{1 + \dfrac{p}{\omega_b}} \tag{29}$$

where $h^{\circ}_{12} = \dfrac{\omega_{ae}}{\omega_e}$.

Transistor Thermal Stability

M. J. HELLSTROM*

The thermal stability of a transistor connected in a general bias circuit, with no signal applied is analyzed. Graphical solutions are necessary to determine stability. Only cases in which temperature variations in input conductance are negligible will be considered. Under certain conditions, frequently satisfied in practice, the general solution may be reduced to one which is more convenient to use. In a slightly smaller class of circuits still another simplification leads to a useful criterion, namely that stability will exist when $SKEI_{c_0}/_{T_1} < 5.3$.

S = dI_{ct}/dI_{co}, Stability Factor[1]
K = Thermal Resistance, °C/W
E = Average Collector to Base Voltage
$I_{c_0}/_{T_1}$ = Leakage Current at a Temperature $T_1 = T_a + KP_o$
T_a = Ambient Temperature
P_o = Collector Dissipation in the Absence of any Leakage Current

In this case the equilibrium junction temperature T_j will not be more than 14.4°C greater than T_1.

A convenient interpretation of the stability factor, S, as well as simple formula for calculating its value are incidental results of the analysis.

Ed Note: This article is based on a paper delivered by the author at the I.R.E. Spring 1958 Technical Conference on Television and Transistors. It appears here in a revised form and includes additional material.

Introduction

THE CIRCUIT in *Fig. 1* represents a transistor connected in a general bias network of resistances and batteries. The network is represented in the familiar four pole impedance parameter notation with the addition of two batteries, which combination completely describes the *d-c* behavior of the bias network. This analysis treats the thermal stability of this system assuming that there are no signals present, i.e., power dissipation in the collector junction is the product of the *d-c* voltage and the *d-c* current. In practice the dissipation may be more or less than this value. The results, therefore, should be used with judgement. For example for a Class A amplifier, since the collector dissipation with a signal is less than with no signal, it might be argued that this analysis is pessimistic. However, the system should be stable in the event of removal of the driving signal. One other assumption is that the emitter to base voltage is zero. This is equivalent to saying that the *d-c* source impedance for the emitter is higher than the *d-c* input resistance to the emitter.[2] Finally, the variation of current gain with temperature is discussed briefly although it has been neglected in the analysis.

The simplest, and perhaps most useful, method will be given first. This will be followed by a very general solution. In this way the necessary conditions for the validity of simple cases will be revealed.

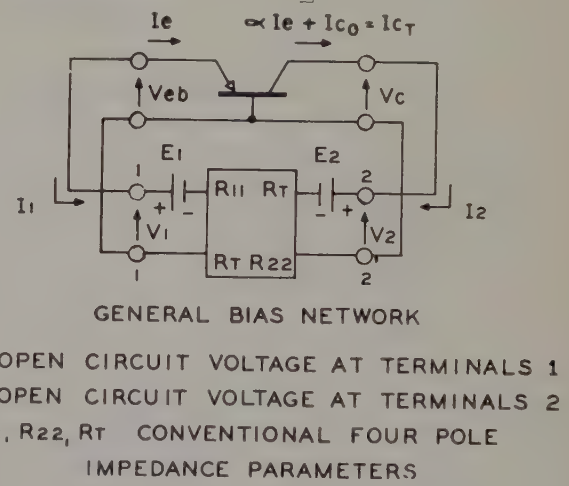


Fig. 1—Circuit representation of a transistor in a general bias network.

Collector Voltage Independent of Temperature

The quiescent collector current consists of a first part which is independent of the collector leakage current, I_{c_o}, and hence of temperature, and a second part which is proportional to I_{c_o}.

$$I_{c_t} = I_c + SI_{c_o} \tag{1}$$

Where I_{ct} = total collector current
I_c = part of the collector current independent of temperature, i.e., value of collector current if leakage current is zero.
S = first derivative of total collector current with respect to leakage current.

* Westinghouse Electric Corporation, Television-Radio Division, Metuchen, New Jersey

[1] R. F. Shea, Principles of Transistor Circuits, John Wiley, Pg. 99.

[2] This is described more fully in the Appendix.

If the bias circuit is such that the collector to base voltage is essentially independent of collector current within the expected range of variation of I_{ct}, then the power dissipated in the junction is:

$$P_c = EI_c + SEI_{c_o} \qquad (2)$$

Where P_c is the total power dissipated in the transistor

E is the collector to base voltage.

The temperature of the junction, T_j, is given by:

$$T_j = T_a + KP_c \qquad (3)$$

Where K is the thermal resistance between the junction and the heat sink,

T_a is the temperature of the heat sink.

Combining these two equations, the junction temperature equilibrium equation is obtained.

$$T_j = T_a + KEI_c + SKEI_{c_o} \qquad (4)$$

The temperature dependence of I_{c_o} is given by:

$I_{c_o} = I_{c_o}|_{T_1} \exp k\ (T_j - T_1)$

Where $I_{c_o}|_{T_1}$ = leakage current at reference temperature T_1.

k = constant, approximately 1/14.4° C for germanium.

T_1 = arbitrary reference temperature.

Inserting this leakage current variation with temperature, the equilibrium equation becomes:

$T_j = T_a + KEI_c + SKEI_{c_o}|_{T_1} \exp\ (T_j - T_1)\ k$

The solutions of this equation, if they exist, may be obtained graphically. The work can be considerably simplified, however, if a special choice of the reference temperature for I_{c_o} is made.

Let $T_1 = T_a + KEI_c$

Then, at equilibrium,

$$(T_j - T_1) = SKEI_{c_o}|_{T_1} \exp\ (T_j - T_1)\ k \qquad (5)$$

This equation is plotted in *Fig. 2*. The value of $SKEI_{c_o}|_{T_1}$ is selected along the ordinate axis and the intersections with the curve represent equilibrium points. Only the intersection at the lower temperature is stable however. This can be seen when it is observed that above the curve the heating rate exceeds the cooling rate, conversely, below the curve the junction cools faster than it heats up.

The most useful feature of the analysis, however, is the fact that there is a maximum value that $SKEI_{c_o}|_{T_1}$ can have if the system is to be stable. For if it exceeds the peak value of the curve in *Fig. 2*, then there are no solutions to the equilibrium equation. By maximizing $x\ exp(-kx)$ it can be shown that this maximum is $1/ke$, or about 5.3 for germanium. It occurs at $x = 1/k$, or 14.4 degrees centigrade.

Thus, the conclusion is that in a circuit in which the collector voltage is constant, equilibrium will be reached only if

$SKEI_{co}|_{T1} < 5.3$

Where $T_1 = T_a + KEI_c$

Note that T_1 is the temperature the junction would reach if there were no leakage current. The value of I_{c_o} at that temperature may quickly be estimated from its room temperature value by using the approximate relation that it doubles for every 10 degrees centigrade rise in temperature.

Before proceeding to the more rigorous analysis a short example of the utility of this criterion will be given.

EXAMPLE:

A Class A Transformer coupled transistor amplifier is to operate at a quiescent point of 10 volts and 1/2 ampere. The heat sink temperature will be 35 degrees centigrade. The leakage current at 35 degrees C. is 2 *ma*. The thermal resistance to the heat sink is 6 degrees centigrade per watt. The problem is to find the stability factor, S, which is required to prevent thermal runaway.

First, calculate the equilibrium junction temperature if I_{c_o} were zero. The quiescent power dissipation in that case is $10 \times 0.5 = 5$ watts. Thus, $T_1 = 35 + 5\,K = 35 + 30 = 65$ degrees centigrade. Thus $I_{c_o}|T_1$ is $(2\ ma) \times 8 = 16\ ma$. Thus

$SKEI_{c_o}|T_1 = S\ (6)\ (10)\ (.016) = 0.96S$

and if this factor is to be less than 5.3, then

$$S < \frac{5.3}{0.96} = 5.52$$

Diodes

The simple stability criterion derived in this section may be applied directly to reverse biased diodes. In this case S is unity and I_c is the temperature independent component of reverse current. The reference temperature, T_1, is determined from the power dissipation due to this current and the applied reverse voltage.

Variation of Critical Value

The peak value of the curve in *Fig. 2* is $1/ke$, where e is the Napierian base and k the coefficient of temperature in the exponential expression for leakage current. For germanium k will range from about .06 to .09 hence the peak value of *Fig. 2* may range from 6.12 to 4.09. If the temperature dependence of the leakage current of a given transistor is known, the actual value of k may be determined and the curves may be scaled accordingly.

Also, silicon transistors have a value of k which is approximately half the value for germanium. For example, the manufacturers data on the T1952 gives a value of 1/23°C over the range 0-100°C. The curves for this transistor should therefore be scaled by 23/14.4 or 1.62. Hence the critical value is $5.3 \times 1.62 = 8.58$. The abscissa is also scaled by the same factor, that is one C° becomes 1.62 centigrade degrees.

Complete Analysis

In the Appendix the collector current and voltage are each shown to have two components.

$$I_c = I_c' + S_i I_{c_o} \quad (6)$$

$$V_c = V_c' + S_v I_{c_o} \quad (7)$$

Where I'_c = collector current when I_{c_o} vanishes

V'_c = collector voltage when I_{c_o} vanishes

S_i = constant of proportionality between collector current, I_c, and leakage current, I_{c_o}. This is Shea's Stability Factor.

S_v = constant of proportionality between collector voltage, V_c, and leakage current, I_{c_o}.

The power dissipated in the collector is therefore:

$$P_c = -V_c I_c = -V_c' I_c' - (S_i V_c' + S_v I_c')\, I_{c_o} - S_i S_v\, I_{c_o}^2$$

$$= C_1 + C_2(I_{c_o}) + C_3(I_{c_o})^2 \quad (8)^3$$

The problem of thermal stability involves the simultaneous solution of this equation and Equation (3).

$$T_j = T_a + KP_c.$$

The nature of the solutions may be studied by examining the coefficients C_1, C_2 and C_3 of equation (8).

$$C_1 = -\frac{\alpha E_1[E_2(R_{11}-\alpha R_t)+E_1(\alpha R_{22}-R_t)]}{(R_{11}-R_t)^2} \quad (9)$$

$$C_2 = -\left[\frac{\alpha E_1 \Delta R}{(R_{11}-\alpha R_t)^2} + \frac{R_{11}[E_2(R_{11}-\alpha R_t)+E_1(\alpha R_{22}-R_t)]}{(R_{11}-\alpha R_t)^2}\right] \quad (10)$$

$$C_3 = -\frac{R_{11}\Delta R}{(R_{11}-\alpha R_t)^2} \quad (11)$$

From Equation (8) it is evident that C_1 is the value of the collector dissipation when I_{c_o} is zero. C_1 must, in practice, be positive. C_2, however, which is the proportionality constant between P_c and I_{c_o}, can be positive, negative or zero. This means that as I_{c_o} increases, the collector dissipation could, as a result of this term, decrease, increase or stay the same. Finally, C_3, the second derivative of the collector dissipation with respect to I_{c_o}, is always negative.[4] The effect of this term as I_{c_o} increases is to cool the junction. In addition, for any $C_3 < 0$ there will always be an equilibrium point. This equilibrium will be at a very high temperature in general. It is, therefore, not useful in practice.

Graphical solutions to equation (8) have been presented in the literature,[5] however, it was apparently not recognized that C_2 could be negative. When C_2 is negative, equilibrium will always be attainable.

Curves for this case have been prepared. They are useful in obtaining the equilibrium value of junction temperature although they are not needed to determine stability since it always exists when C_2 is negative or zero. These curves are shown in *Fig. 3* along with a few cases of C_2 positive. The form of presentation utilizes the same technique of choosing the reference temperature for I_{c_o} that was used in the simple case.

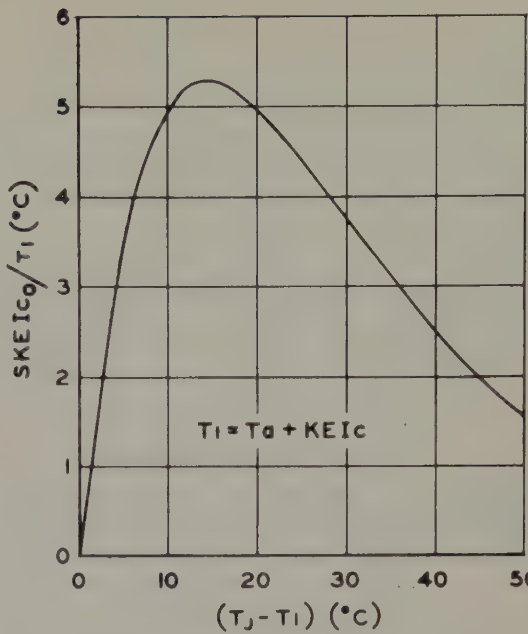


Fig. 2—Plot of Equation (5).

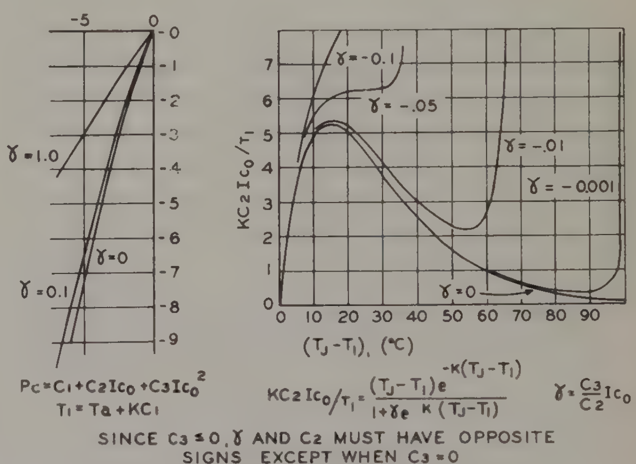


Fig. 3—Graphical solutions for Equation (8) for both positive and negative values of C_2

A particular case of interest occurs when the last term in (8) can be neglected, that is, when

$$|C_3 I_{c_o}| < |C_2| \quad (12)$$

Then the equilibrium equation is

$$T_j = T_a + K\,[C_1 + C_2 I_{c_o}].$$

Letting $T_1 = T_a + KC_1$ and $T_j' = (T_j - T_1)$ this may be written,

$$T_j' = KC_2 I_{c_o}|T_1 \exp(kT_j')$$

$$\text{or, } T_j' \exp(-kT_j') = KC_2 I_{c_o}|T_1 \quad (13)$$

[3] Handbook of Semiconductors—Hunter, pp. 13-12.

[4] This is because, in equation (11) R_{11} is positive, $\Delta R = (R_{in_{s.c.}})R_{22}$ is positive and, of course, the denominator is positive.

[5] Hunter, ibid.

Equation (13) is plotted in *Fig. 4* for positive and negative values of C_2. It is apparent that equilibrium will be established for all values of $KC_2I_{c_0}|_{T_1}$ less than 5.3, which of course includes all negative values. Thus the condition (12) on the system describes the validity of the type of analysis presented earlier in this report. *Fig. 3* shows this qualitatively.

One additional assumption is necessary for the original simple analysis. It is that the collector voltage is constant. Referring to Equation (8) it is evident that this is equivalent to saying

$$|S_v I_c'| < |S_i V_c'| \qquad (14)$$

In terms of the system this can be written:

$$\left|\frac{\alpha \Delta R\, E_1/R_{11}}{(R_{11}-\alpha R_t)^2}\right| < \left|\frac{R_{11}/\alpha}{(R_{11}-\alpha R_t)^2} \times \frac{E_2(R_{11}-\alpha R_t) + E_1(\alpha R_{22}-R_t)}{R_{11}-\alpha R_t}\right| \qquad (14A)$$

It will be shown in the next section that $S_v = (R_{2s \cdot c \cdot}) S_i$. With this, Equation (14) becomes

$$|I_c' R_{2_{s.c.}}| < |V_c'| \qquad (14B)$$

a form of the criterion which is frequently easier to apply than the preceding forms. When this condition is satisfied as well as that given in Equation (12), then the solution of (13) as given in *Fig. 4* may be expressed as in the simple analysis at the beginning of this report in *Fig. 2*.

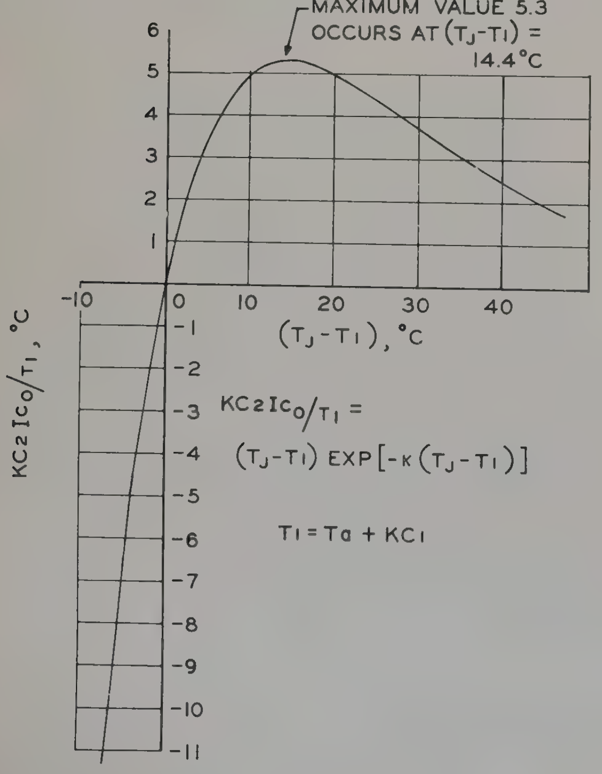


Fig. 4—Graphical solution for Equation (13) under the special conditions set forth in the text.

Stability Factors, S_i and S_v

From the analysis as given in the Appendix and using four pole network theory some feeling may be had for the stability factors S_v and S_i of Equations (6) and (7) and for the operation of a bias network in reducing temperature effects. In addition, these concepts facilitate the calculation of these stability factors.

From the appendix the first derivative of the collector current with respect to leakage current is

$$S_i = \frac{1}{1-\alpha\dfrac{R_t}{R_{11}}}$$

Refer to *Fig. 5* which is the same as *Fig. 1* except that the emitter connection is open circuited and the batteries are omitted since we are interested only in changes. If one ampere (change) is supplied to the

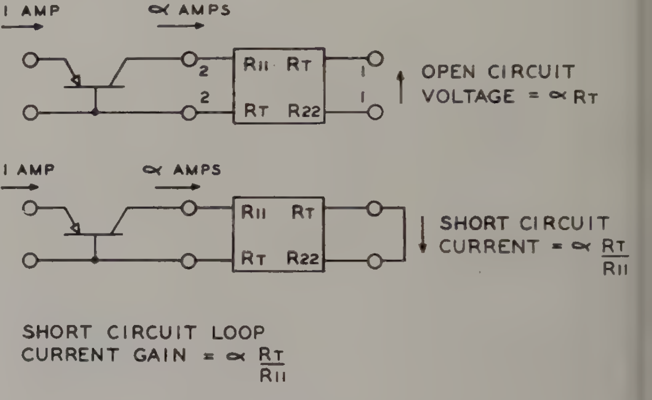


Fig. 5—Schematic representation similar to that of Fig. 1. Emitter connection, however is open, and batteries are omitted.

emitter then α amperes will flow from the collector into terminal 2 of the bias network. The voltage appearing at the open terminals 1 of the bias network will be $\alpha\, R_t$. If now terminals 1 were short circuited, the output current would be $\alpha\, R_t/R_{11}$ in the direction shown. Thus, the significance of this factor is that it is the short-circuit open-loop current gain. Closing the loop with the emitter circuit does not alter this gain figure because the emitter-base impedance is assumed to be zero.

The effect of leakage current on collector current may be calculated, as in *Fig. 6*, by assuming a current source, I_{c_0}, applied to the collector terminal of a feedback amplifier.

From *Fig. 6*,

$$I_{c_0} + \alpha\frac{R_t}{R_{11}} I_c = I_c$$

$$I_c = \frac{I_{c_0}}{1-\alpha\dfrac{R_t}{R_{11}}}$$

Thus the change in I_c due to a change in I_{co} is modified by the feedback factor $(1 - \alpha R_t/R_{11})$.

The meaning of S_v, the first derivative of collector voltage with respect to leakage current, may be shown in a similar manner. From the Appendix:

$$S_v = \frac{\Delta R/R_{11}}{1 - \alpha \dfrac{R_t}{R_{11}}}$$

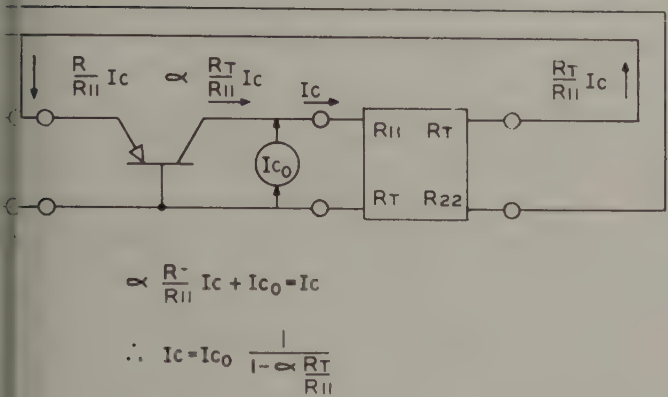


Fig. 6—Assumed current source, I_{co}, enables the effect of leakage current on collector current to be calculated.

But $\Delta R/R_{11}$ is the impedance looking into the output terminals 2 of the network when the input terminals 1 are short circuited. This is actually the impedance seen by the collector since the emitter represents a short circuit termination of the network. Thus,

$$\Delta R/R_{11} = R_{2_{s.c.}} = \frac{dV_c}{dI_c}$$

Since $S_v = \dfrac{dV_c}{dI_{c_o}} = \dfrac{dV_c}{dI_c}\,\dfrac{dI_c}{dI_{c_o}}$ it follows that

$$S_v = R_{2_{s.c.}}\, S_i \tag{15}$$

In a similar manner the coefficient C_3 in Equation (8) may be shown to be

$$C_3 = -R_{2_{s.c.}}\,(S_i)^2$$

Effect of Temperature Variation of α

The variation in transistor current gain with temperature will modify the value of the current stability factor S_i. The reported[6] increase of current gain with temperature is a regenerative effect because it increases S_i as temperature increases. This has not been included in the present analysis, but the following considerations enable an evaluation of its significance.

The stability factor S_i may be written in terms of common emitter current gain, β, and the bias network s.c. current gain, G.

$$S_i = \frac{\beta + 1}{\beta\,(1-G) + 1} \qquad \text{where } G < 1$$

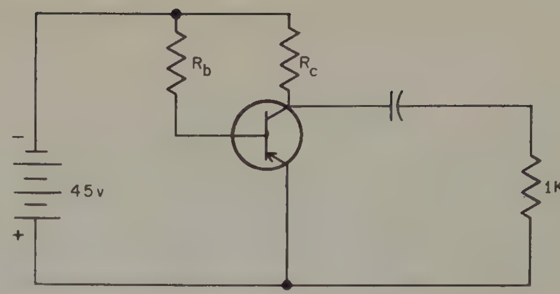


Fig. 7—Amplifier circuit used in the illustrative design example.

If the bias network gain, g, is unity when S_i has its maximum value, $(\beta + 1)$, as is expected from the definition of S_i. Differentiation of this expression gives the dependence of S_i on β.

$$\frac{dS_i}{d\beta} = \frac{G}{[\beta(1-G) + 1]^2} = G\,\frac{(S_i)^2}{(\beta+1)^2}$$

$$\text{or} \qquad \frac{dS_i}{d\beta} = G\,\frac{(S_i)^2}{(S_{i\ max.})^2}$$

Thus, if G is adjusted so that the stability factor is 1/2 its maximum value, then the variation of S_i with temperature is approximately 1/4 a small variation in β. For larger variations the incremental dependence does not give an accurate picture, however, it is significant that the sensitivity of S_i with respect to β is reduced roughly as the square of the ratio of the reduction in S_i.

For transistors whose variation of β with temperature is large the results of this report should be used with a bit more caution.

Illustrative Example

Collector Voltage highly dependent on Leakage Current

An *RC* coupled Class A amplifier is to be designed using the circuit shown in *Fig.* 7. The transistor has a beta of 50 and a room temperature leakage current of 1 microampere. The thermal resistance to the ambient is 240° C/w. The maximum current rating is 10 milliamperes.

To obtain maximum output power it is desirable to operate in the center of the collector current aperture. Thus $I_c = 5\ ma$ is the desired quiescent current. Since the load resistance is 1 *K* the quiescent collector voltage, V_c, should be near 5 volts to minimize device dissipation. From this R_c is calculated

$$R_c = \frac{45 - 5}{5} = 8{,}000 \text{ ohms.}$$

$$\text{Since} \quad \text{beta} = 50,\ R_b = \frac{45}{.005/50} = 450 \text{ Kilohms}$$

Up to this point I_{co} and thermal stability have been

[6] R. F. Shea—"Transistor Circuits" pp. 45, John Wiley & Sons.

neglected. To calculate S_i the open look current given is found to be unity. (See *Fig. 8*)

Therefore $$S_i = \frac{1}{1-\alpha} = 51$$

Then, calculate $R_{2s.c.} = R_c$, so $I_c'R_{2s.c.} = (.005)\ (8{,}000) = 40$ volts which, since it is greater than $V'_c = 5$, does not satisfy Equation (14B). Therefore the simple analysis does not apply. C_2 may readily be calculated from Equations (8) and (15):

$$S_v = R_{2_{s.c.}}\ S_i = 408{,}000\ \Omega$$

$$C_2 = -[(51)(-5) + (408)(5)]$$
$$= -[-255 + 2040]$$
$$= -1785 \text{ volts}$$

The magnitude of C_3 is found by noting that

$$C_3 = -R_{2_{s.c.}}\ S_i^2$$
$$= -(8000)(51)^2 = -20{,}808{,}000$$

Thus if $I_{co}|_{T1}$ is x microamperes, applying equation (12):

$$x < \frac{1785}{20.8} = 80.6\ \mu_a$$

in order for the curve in *Fig. 4* to be useful. This is very likely to be true and will be verified at the end of the calculation. Thus,

$$T_1 = T_a + KC_1$$
$$= 25 + (240)(.025)$$
$$= 31^\circ\ C$$

Calculate $I_{c_o}|_{31^\circ C}$

$$I_{c_o}|_{31^\circ C} = (1 \times 10^{-6}) \exp^{\frac{31-25}{14.4}} = 1.518 \times 10^{-6} \text{ amps}$$

which certainly satisfies the condition for neglecting C_3 and allows the use of *Fig. 4*. From this figure at

$$KC_2 I_{c_o}|_{T_1} = (240)(-1785)(1.518 \times 10^{-6})$$
$$= -.65$$

the junction temperature at equilibrium is found to be

$$T_j = T_1 - 1^\circ = 30^\circ\ C$$

Thus, there is no danger of thermal damage in this circuit. The actual quiescent values of current and voltage can be calculated from Equations (6) and (7). First

$$I_{c_o}|_{30^\circ} = I_{c_o}|_{25^\circ} \exp^{\frac{30-25}{14.4}} = 1.416 \times 10^{-6} \text{ amperes}$$

hence, $$I_c = (5 \times 10^{-3} + 51\ (1.416 \times 10^{-6})$$
$$= 5.072\ ma$$
$$V_c = -5 + (408{,}000)(1.416 \times 10^{-6})$$
$$= -4.42 \text{ volts}$$

Experimental Verification

A fair experimental verification of the results of the analysis has been obtained. The procedure was as follows:

1. Leakage current for a power transistor was measured at 1 and 6 volts on the collector and over the temperature range of 27°C to 88°C. The results plotted on semi-log paper were well approximated by the straight line:

   $$I_{c_o} = (1 \times 10^{-3}) \exp\ (T_j - 55^\circ C)/14.4.$$

   The leakage current doubles for a 10°C rise in junction temperature, T_j. It does not change as the collector voltage went from 1 to 6 volts, indicating that this was essentially saturation current, non-ohmic in nature. This leakage current data was used to calculate the thermal resistance between the junction and the mounting base.
2. The power transistor was mounted on a 5 square inch aluminum heat sink and connected in the simple unstabilized bias circuit shown in *Fig. 9*. R_b was adjusted for different collector currents and the system was permitted to heat up. Measurements of power and junction temperature in the stabilized condition enabled the calculation of the system thermal resistance, K. Measurements for two conditions of power are described here.

A. *STABLE*

The base resistance, R_b, was set for a collector current of 150 *ma* when the circuit is first turned on, i.e., when the mounting base of the transistor is at 25°C. Large signal current gain is 67 at this current. The collector current, collector to emitter voltage and mounting base temperature are plotted in *Fig. 10* as a function of time. The drop in collector voltage is attributed to discharge of the supply battery. At equilibrium the collector dissipation is 17 (.253) = 4.3 watts. The thermal resistance from the mounting base to the ambient is then (55-25)/4.3 = 6.98°C/W. The manufacturers' value for thermal resistance between the mounting base and the junction is 2.2°C/W, maximum. I_{c_o} measurements indicated it was closer to 1°C/W on this unit. Therefore, take the total thermal resistance as 8°C/W.

T_1 can now be evaluated using the terminal value of V_{ce}.

$$T_1 = 25^\circ C + (17 \text{ volts})(.15 \text{ amps})(8^\circ C/W)$$
$$= 45.4^\circ C$$

Therefore, $$I_{c_o}/_{T_1} = (1 \times 10^{-3})\ e^{\left(\frac{45.4-55}{14.4}\right)} = 0.513\ ma.$$

Finally, $$SKEI_{c_o}/_{T_1} = (70)(8^\circ C/W)(17 \text{ volts})$$
$$(0.513 \times 10^{-3} \text{ amps})$$
$$= 4.88$$

From *Fig. 4* a system with this value of $SKEI_{c_0}|_{T_1}$ should stabilize at a junction about 10°C above T_1, or 55.4°C. This corresponds to a mounting base temperature of 51.1°C. The collector current at equilibrium would be

$$I_{c_t} = I_c + SI_{c_0}/_{55.4°C}$$
$$= 150 + 70\ (1\times10^{-3}) = 223\ ma.$$

Referring to the experimental curves, the equilibrium temperature and current show fair correlation with these calculated values.

B. *UNSTABLE*

The value of R_b was adjusted for an initial ($T_{mb} =$ 26°C) value of 208 *ma*. Large signal current gain 71. Measured quantities behaved as shown in *Fig. 11*.

This test was discontinued to prevent damage from the incipient runaway. The collector to emitter voltage remained substantially constant at 16 volts.

$$T_1 = 26°C + (8°C/W)\ (16\ \text{volts})\ (.2\ \text{amps}) = 51.6°C$$

$$I_{c_0}/_{T_1} = (1\times10^{-3})\ e^{\frac{51.6-55}{14.4}} = 0.79\ ma$$

Finally, $SKEI_{c_0}/_{T_1} = (71)\ (8°C/W)\ (16\ \text{volts})\ (0.79\ ma)$
= 7.18, which exceeds the critical value of 5.3.

Hence it is to be expected that this system would not stabilize.

Appendix

From *Fig. 1*:

$$V_1 = E_1 + I_1 R_{11} + I_2 R_T$$

$$V_2 = E_2 + I_1 R_T + I_2 R_{22}$$

Set $V_2 = V_c,\ V_1 = Veb = 0,\ I_2 = \alpha I_e + I_{c_0} = I_c,\ I_1 = -I_e$:

$$I_c = \left(\frac{\alpha E_1}{R_{11} - \alpha R_T}\right) + I_{c_0}\left(\frac{1}{1 - \alpha\ \dfrac{R_T}{R_{11}}}\right)$$

$$V_c = \left[\frac{E_2(R_{11} - \alpha R_T) + E_1(\alpha R_{22} - R_T)}{R_{11} - \alpha R_T}\right] + I_{c_0}\left(\frac{\Delta R}{R_{11} - \alpha R_T}\right)$$

The power dissipated in the transistor is:

$$P_c = -V_c I_c$$

$$P_c = -\left[\frac{\alpha E_1 [E_2(R_{11} - \alpha R_T) + E_1(\alpha R_{22} - R_T)]}{(R_{11} - \alpha R_T)^2}\right]$$

$$-I_{c_0}\left[\frac{\alpha E_1 \Delta R + R_{11}[E_2(R_{11} - \alpha R_T) + E_1(\alpha R_{22} - R_T)]}{(R_{11} - \alpha R_T)^2}\right]$$

$$-I_{c_0}^2\left[\frac{\Delta R\ R_{11}}{(R_{11} - \alpha R_T)^2}\right].$$

where $\Delta R = R_{11} R_{22} - R_T^2$

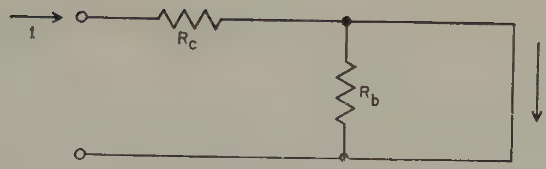


Fig. 8—An open loop current gain of unity used in the calculation of S_i.

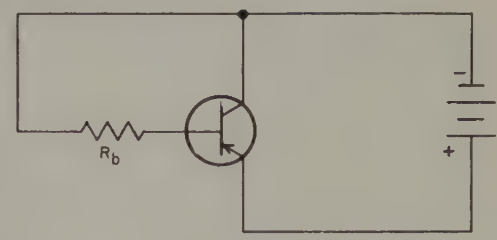


Fig. 9—Unstabilized bias circuit used in experimental verification.

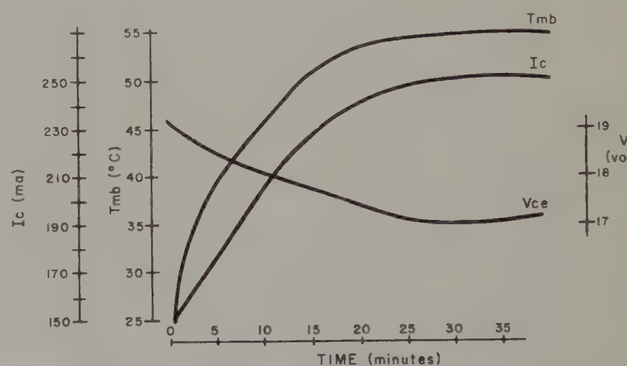


Fig. 10—Plots of collector current, collector to emitter voltage, and mounting base temperature versus time for the stable case.

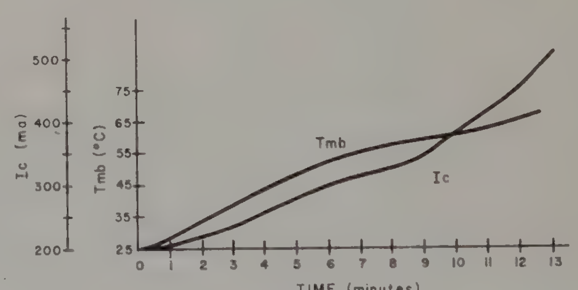


Fig. 11—Variation of collector current and mounting base temperature with time for the unstable case.

The approximation that the emitter to base voltage is zero is made above when $V_1 = V_{eb}$ is set to zero. The equation involved is

$$E_1 - V_{eb} = -(I_1 R_{11} + I_2 R_T),$$

from which the approximation may be more precisely defined as

$$V_{eb} \ll E_1.$$

In other words, the emitter to base voltage must be much less than the d-c voltage seen looking into the bias network at the emitter–base terminals with the transistor out of the socket, i.e., the open circuit Thevenin input voltage.

For the example given in page 12, E_1 is 45 volts. Therefore the approximation is certainly valid.

A Glass Transistor Enclosure

ROGER K. WHITNEY*

At the 1958 Radio Engineering Show an all glass transistor enclosure was shown to the semiconductor industry.[1] The final closure of this unit was made possible through the use of a patented electric heating technique. Licenses are available so that semiconductor device manufacturers can utilize this process. The localized heating achieved by this technique does not exceed the stringent temperature limitations of sensitive semiconductor assemblies. This article will describe the basic technique that was used to make this all glass enclosure possible.

PRINCIPLES of electrical heating and working of glass were developed by Dr. E. M. Guyer of the Corning Glass Works. The following description in his patent describes the electric heating phenomena that are utilized.

"It has been known to those skilled in the art that glass can be heated by passing a current therethru once it has been heated to a sufficient temperature. Actually, several factors besides temperature have a part in determining whether or not glass will conduct electricity. These are the voltage and frequency of the impressed potential, the wave shape, if an alternating potential be used and the composition and geometry of the piece of glass. This conduction is entirely apart from the disruption of glass at high voltages by puncture. As the frequency of a given impressed voltage goes up it becomes increasingly easy to pass a current of electricity through the glass. Advantage may be taken of this phenomena by lowering the impressed voltage or operating on glass at a lower temperature. Accordingly, it is possible to strike directly into glass at room temperature if sufficiently high frequencies and voltages are employed, but sources of such potentials are difficult and costly to provide, and it is usually preferable to locally heat the glass through which it is desired to pass a current to lower the frequency and voltage relationship at which it will become conducting.

"The fact that glass must be heated by some auxiliary means before it will become conducting at most available voltages and frequencies, has materially limited the application of heating by electrical conduction in the glass working art. Such few applications as have been made, have been confined primarily to furnaces, but there the tendency of current to channel along the already hottest path has proven a major obstacle. In the present invention this tendency of the current to flow along the hottest paths has been utilized to create hot zones in glass of very restricted area. In order to render the glass conducting, it is first heated by passing a spark discharge between two electrodes along the surface of the glass in the region where it is desired to form the hot stripe. . . . As the glass along this line is raised in temperature its resistance is lowered until it becomes less than the air gap across its surface at which time it commences to carry current. From this time on, heat is developed in the glass very rapidly since as the temperature goes up the current increases, and heat is developed as a function of the square of the current. . . .

"The process of heating glass has many advantages over any hitherto known in the art. It is far more rapid than any form of convection, radiation, or conduction heating in which heat is developed in some external source and transmitted to the glass. . . . Due to the simultaneous generation of heat all along the path of current flow it is possible to obtain uniform temperature conditions throughout the entire heated stripe and so eliminate hot spots and boiling.

"A further advantage of this type of heating is that the maximum temperature to which the glass is raised may be easily and accurately controlled. . . ."[2]

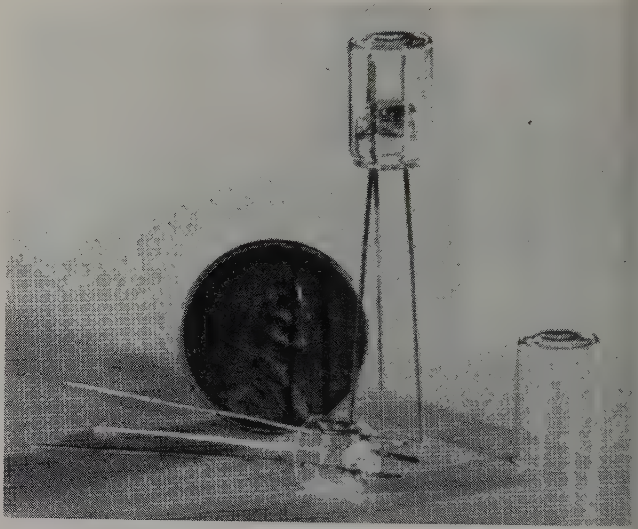


Photo showing comparative size of enclosure.

Enclosure Design

Combining the advantages outlined in this patent with certain physical dimensions and geometric configurations provided the solution to glass encapsulation of transistors.

Since the Corning Glass Works is not a manufacturer of semiconductor devices, it was deemed advisable to design an enclosure which could be used with a minimum amount of difficulty by device manufacturers. For this reason, the JETEC Group 30 diameter and lead configuration were selected as being the most widely and commonly used throughout the industry. Although the JETEC Group 30 form factor is not present in this glass unit, the diameter of the bulb and the lead configuration of the stem are compatible with existing standards (see *Figs. 1* and *2*).

The stem configuration is such that it can be fab-

* Corning Glass Works.

1 Corning Glass Works Announcement.

2 E. M. Guyer: "Glass Heating and Working," Patent Number 2,306,054.

…cated on conventional stem machines already in use by the electronic tube industry. Wall thicknesses for both the bulb and stem were kept as thin as is consistent with good mechanical strength. The thin walls allow a minimum amount of heat to be applied in the shortest interval of time and still achieve a good seal. The "cup" shape of the stem provides sufficient distance from the seal area to the sensitive device so that its critical temperature is not exceeded. The resultant internal volume of gases in the unit, which becomes heated somewhat, provides enough positive pressure after closure to round out the inside contour at the sealed area.

Materials

A question was posed as to what lead material and glass composition should be used. Both must be inexpensive and suitable for large volume production to the accuracies required. In addition, the materials should be familiar to the semiconductor industry. For several years diode manufacturers have been encapsulating their devices in Corning 0120 Glass and using Dumet, or equivalent alloy, leads. The reliability of these materials is well known throughout the electronic industry and both are inexpensive.

Fabrication Equipment

At this writing all sealing work has been done with the simplest of equipment. In this way the fundamental operation can be studied and perfected without the encumbrance of complicated machinery.

Basic equipment used:

1. Glass working lathe, positive drive for head stock and tailstock with tool support and tailstock movable along the lathe bed. Spindle speeds of 120 to 140 rpm were most satisfactory.
2. Transformer
   - 115 volt primary
   - 60 cycle
   - 15,000 volt secondary
   - 450 VA
3. Variable reactor (General Radio Company V20H or equivalent) 230 volt, 8 ampere rating. Actually, the maximum output of this unit is greater than the primary windings of the transformer should handle.
4. Two tungsten electrodes .080″ diameter sharpened to a point.
5. Appropriate insulators to mount electrodes to the lathe tool support.
6. Shielding and protective devices to prevent the operator from accidentally contacting the high tension side of the circuit when the power is on. The lathe itself is grounded.
7. A foot switch in the primary circuit was found to be more advantageous than a hand operated switch.
8. A carbon or Graphitar tool is mounted on, but insulated from the lathe tool support. The basic

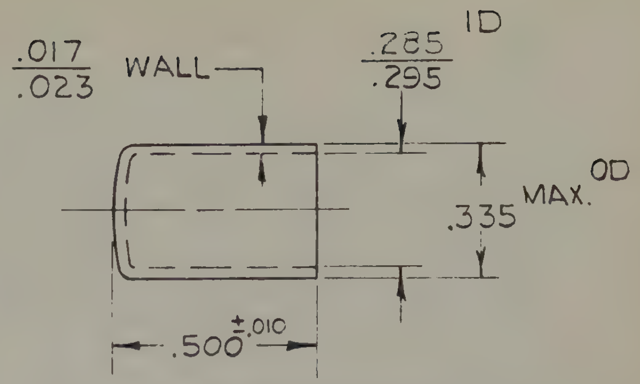


Fig. 1—Bulb Dimensions.

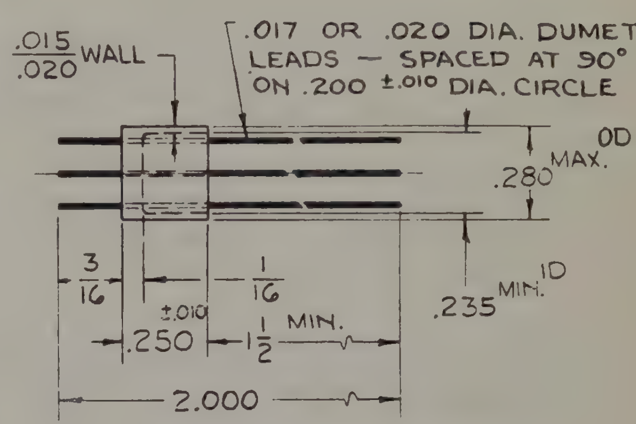


Fig. 2—Transistor stem dimensions.

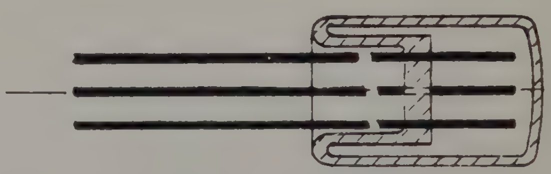


Fig. 3—Assembled Unit.

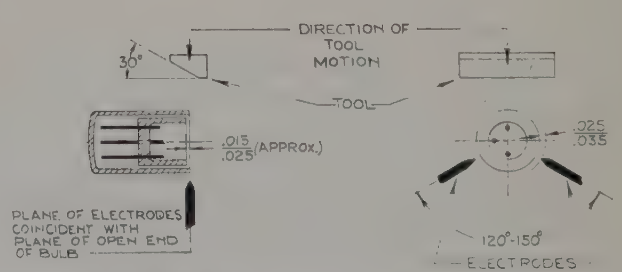


Fig. 4—Relationship of glass, electrodes, and tool.

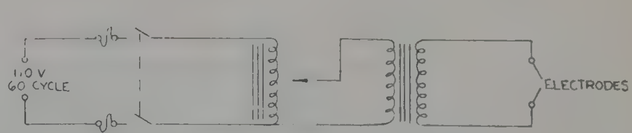


Fig. 5—Electric sealing circuit.

shape of this tool is shown in *Fig. 4*. It is actuated manually by an insulated linkage.

9. A brass collet is used in the headstock to hold the bulb. This collet is insulated from the headstock, but is of sufficient size to act as a heat sink. The inside diameter of this collet (.330″) results in the bulb being gripped by a force fit. The collet is slotted to provide allowance for slight variations in bulb diameter. An insulated pushrod through the headstock is used to remove the bulb from the collet.
10. The stem leads are held by a metal holder which is supported in, but insulated from the tailstock. This holder grips most of the free lead length, and is itself a heat sink as well as a common electrical junction for the leads.

The relationship of the glass parts, the electrodes, and the tool at the start of the heating operation are shown in *Fig. 4*. The electrical circuit is indicated in *Fig. 5*.

Low frequency (60 cycle) equipment was selected due to its initial low cost and ease of procurement. High frequency equipment has not been fully utilized to date.

Caution: Voltages used in this circuit are lethal. Under no circumstances should human contact be made with "HOT" elements. Be sure all insulators and shields are adequate.

Procedure and Technique

The detailed steps of the sealing operation follow. A bulb is inserted into the collet, closed end first, to sufficient depth to allow one eighth of an inch at its open end to be exposed. The stem is inserted in its holder and gripped by approximately one inch to one and one quarter inches of the free lead length.

Initially, it was felt that an insulating shield should be used between the leads and the inside diameter of the stem. This shield would prevent undue heating of the leads by the arc. Recent work has revealed that this Vycor tubing shield is not necessarily needed to make good units.

The bulb and stem are brought together so that the plane of the open end of the stem is .015″ to .025″ inside the plane of the open end of the bulb (see *Fig. 4*). The outside diameter of the stem should be concentric with the inside diameter of the bulb. This feature is actually built into the accuracy of the lathe and the appropriate holders. Fair seals can be made with bulbs and stems eccentric to one another, but optimum results require good concentricity.

The electrodes are adjusted so that their included angle is less than 180°. Good results have been achieved with angles of 120° to 150°. Experience has shown that non-uniform heating results if the electrodes are placed diametrically opposite one another. The plane of the center line of the electrodes is coincident with the plane of the open end of the bulb. The tips of the electrodes are adjusted so that a .025″-.035″ clearance is maintained around the bulb (see *Fig. 4*).

The carbon tool is designed and counter balanced so that only a small force is exerted on the glass. This amounts to one-fourth to one-half an ounce. The tooling action is by the weight of the tool itself. This action is applied intermittently to reduce the chill effect of the tool. The 30° angle at the tool face forces the softened bulb glass into contact with the stem glass (see *Fig. 4*).

With the glass parts, electrodes, and tool in the proper position, heating and sealing can be accomplished. The initial setting of the variable reactor is at 60 volts. This unit is wired in the circuit so that its output is of the same magnitude as its scale reading. With the circuit closed, the arc travels across the air gap between the electrodes. The "splash" of this arc plus radiation preheats the glass and brings it up to a temperature where the resistance of the glass is less than that of the air gap between the electrodes. In the case of 0120 glass, this temperature is in the 500° to 600° Centigrade region. If a much higher preheat voltage is used, non-uniform heating of the glass is encountered. This uneven heating produces incomplete seals later in the process. The preheating phase of the cycle takes 6 to 7 seconds. At the end of this time the variable reactor setting is increased to 130 volts according to the schedule outlined below. Since the glass has been brought to conducting temperature, the arc now strikes into the bulb and raises its temperature to the working point of 975° to 1000° Centigrade. At the proper time, (see schedule), the tool is brought intermittently into contact with the bulb to roll the bulb diameter into intimate contact with the stem. This intermittent tooling is continued until the end of the cycle when the power is turned off and the seal is completed.

Time-Voltage Cycle

Time (Seconds)	Voltage	Action
0	60	Preheat
6	60	Preheat
7	80	Heat
14	100	Heat
16	130	Heat
17	130	Tool and Seal
20	0	Complete

In developing this technique, temperature sensitive compounds were employed to indicate actual temperatures achieved. The three leads were bent in such a way that they pointed to a common center inside the envelope. At this intersection, the ultimate location of the germanium or silicon crystal, a drop of "Tempilaq"[3] was applied and dried. This material changes color when it reaches an instantaneous tem-

[3]Manufactured by Tempil Products, New York City

perature of 150° Centigrade or a sustained temperature of 140° Centigrade. Units have been sealed without causing the Tempilaq to change colors.

A small quantity of Dow Corning DC4 silicone grease was introduced into the bulb to dissipate any excessive heat encountered during sealing that might reach the Tempilaq, or the device itself in the case of an actual transistor. Seals using actual transistors were made with and without this silicone grease. In both cases the devices proved to be good units. The addition of grease or a potting compound will obviously increase the power dissipation rating of the unit. It is important that the surfaces to be sealed be free of this grease or potting compound.

No annealing of the completed seal has been included. Such an operation, to be effective, would necessitate that the whole assembly be raised to 440° or 445° Centigrade and held for a period of time that would destroy the unit which has been so carefully encased in glass. Sealed and unannealed samples have been severely abraded without evidence of failure.

Throughout this discussion of the sealing procedure and technique, no mention has been made of a flame. None is required. An arc is used to preheat the glass, and the arc is used to heat the glass to working and sealing temperature. As a result no products of combustion are introduced into the final enclosure. Since no flame is utilized, one can readily visualize that such a process can be done "under a bell jar" or under closely controlled atmospheric conditions.

Conclusion

The discussions in the previous sections have outlined the principle, design, material, equipment, and technique considerations for successfully encapsulating transistors in glass. As with any new process, once the initial breakthrough has been made, numerous unforeseen problems arise. It is not the intent of this article to indicate that all the work on this process has been done. Such is not the case. Further efforts to perfect inexpensive glass enclosures will require the cooperation of the semiconductor industry.

Transistor Switching Circuits

PART 1

A. W. CARLSON*

The purpose of these articles (given in two parts) is to provide description, precautions, formulae, and circuits that may be required by the circuit designer. A discussion is presented on the relationship of switching properties to the small signal equivalent circuit, and the problems of carrier storage and the avoidance of this condition. Also included in this installment is an analysis of multivibrator operation illustrated by circuits and waveforms. The first part gives a description of free-running multivibrator operation, both saturating and nonsaturating types. The second part is about one-shot multivibrators and their trigger pulses with amplitudes of voltages and currents for on-off conditions, biases, and typical values.

TRANSISTORS have found wide application in pulse circuitry by reason of their excellent switching properties, low power consumption, small physical size and high reliability. In this section some typical switching circuits are described and design formulae given.

Some of the desirable properties of a switching transistor may be related to the small equivalent circuit shown in *Fig. 1* which, although only a simple approximation, is valuable in considering transient effects. For high speed switching it is desirable that the current gain (α or β) be high and that C_C and r_b' be low. For example, it may be shown that the maximum (radian) frequency at which the transistor can oscillate is given by[1]

$$\omega_{max} \approx \sqrt{\frac{\alpha_o \, \omega_{co}}{4 \, r_b' \, C_c}}$$

for alloy junction transistors. It is apparent that there is a close correlation between parameter values leading to a high maximum frequency of oscillation and those giving high speed switching.

*Mr. Carlson is a Transistor Applications Consultant for CBS-HYTRON Semiconductor Operations, Lowell, Mass. This article is part of a project to produce a series of articles covering transistor parameters and circuitry and has been released by CBS-HYTRON for publication in Semiconductor Products.

[1]R. L. Pritchard, "High Frequency Power Gain of Junction Transistors," Proc. of the I.R.E., Vol. 43, Sept. 1955, p. 1075. L. J. Giacolletto, "Study of *p-n-p* Alloy Transistors from D-C through Medium Frequencies", R.C.A. Review, Dec. 1954, p. 506.

Carrier storage is an important consideration in high speed switching circuits, particularly in flip-flops, multivibrators and other circuits in which a transistor may be in the conducting state for an appreciable period of time. Difficulties with carrier storage come about when the transistor is operated in the saturated region (both emitter and collector junctions forward biased), resulting in high minority carrier density at the collector. When the transistor is turned off, it is found that there is an appreciable delay, with the collector junction remaining a low impedance, until the minority carrier density at the collector junction has dropped to zero, allowing the transistor to enter the active region for the completion of the turnoff transient. The delay time, due to minority carrier storage, increases as the transistor is driven harder into the saturated region, and may be of the order of several microseconds. The problem of carrier storage may be avoided by preventing operation in the saturated region.

In establishing the *d-c* relationships in the circuits to follow, some simplifying assumptions will be made:

1) when the transistor is cut off, it will be considered removed from the circuit;

2) when the transistor is in the active region, the emitter and base terminals will be considered tied together, and the collector junction represented by a current generator αI_E or βI_B in series with the collector terminal and base and emitter terminals (as in *Fig. 2*);

3) in the saturated region the transistor is considered as having all three terminals tied together.

These approximations are valid in establishing *d-c* relationships under the following conditions:

1) the reverse collector and emitter resistances are very high compared to external resistances;

2) the internal base to emitter resistance is small compared to external resistances;

3) in the saturated condition the collector impedance is low compared to external collector load and;

4) I_{CO} is so small that it may be neglected.

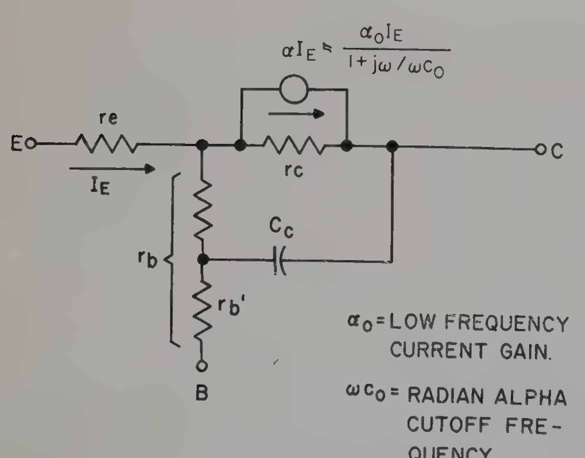


Fig. 1—Small signal equivalent circuit.

The circuits to follow are for *n-p-n* transistors; for *p-n-p* types all supply voltage, diode, and waveform polarities are to be reversed. Otherwise, the circuits apply for both types.

Multivibrators

In *Fig. 3* typical free-running multivibrators are shown, one of the saturating type and one of the nonsaturating type. The saturating type may be satisfactory for low repetition frequencies of a few tens of kilocycles whereas the nonsaturating type will operate at repetition frequencies in the hundreds of kilocycles dependent upon the frequency response of the transistors. For example, repetition frequencies of about 500 kilocycles may be achieved with the 10 megacycle CBS 2N440.

Since the operation of the nonsaturating circuit is essentially the same as that of the saturating cicruit, the saturating circuit will be used to describe circuit operation. *Fig. 4* shows waveforms in an unsymmetrical multivibrator.

The operation of the multivibrator may be explained as follows: Assume that T_1 (*Fig. 3a*) has just been switched on and T_2 off. C_1 charges toward V_{CC} through R_{L2} and, if given sufficient time, the voltage across C_1 becomes approximately V_{CC}. The base of T_2 is held negative (reversed biased) with the base voltage rising toward V_{BB2} as C_2 is discharging through R_{B2}. When the base voltage of T_2 becomes slightly positive (and the voltage across C_2 approximately

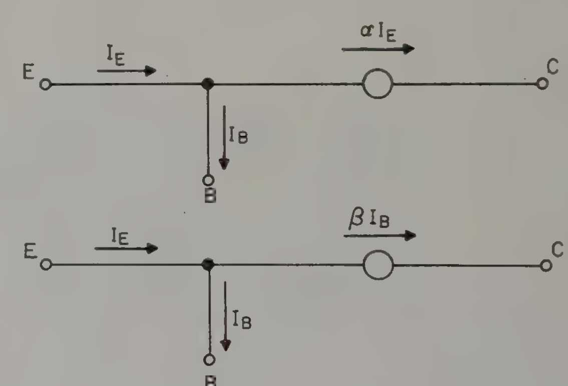


Fig. 2—Approximate equivalent circuits for active region (used for d-c calculation).

zero), T_2 switches on and T_1 is turned off. The base of T_1 is driven negative by about V_{CC} volts (if C_1 is initially charged to V_{CC}) holding T_1 off until C_1 has discharged. During the time that T_1 is held off, C_2 is being charged toward V_{CC} through R_{L1}. The base voltage of T_1 rises exponentially toward V_{BB1} and, when the base becomes slightly positive (voltage across C_1 approximately zero), T_1 turns on and T_2 off. The cycle then repeats.

Under the assumptions that

$$R_{L1} C_2 \ll R_{B1} C_1 \text{ and } R_{L2} C_1 \ll R_{B2} C_2, \qquad (1)$$

(which implies that during the time T_2 is conducting, C_2 is charged to V_{CC}; and during the time T_1 is conducting, C_1 is charged to V_{CC}), the conducting periods and the repetition frequency may be easily expressed.

These assumptions usually apply in practice. It is not necessary that $R_{L1}\,C_2 \ll R_{B1}\,C_1$, for example, for the circuit to operate; if the inequality does not hold, it simply means that C_2 may not become fully charged during the time T_1 is conducting, and although the conducting period is easily determined and expressed, it becomes very difficult to evaluate.

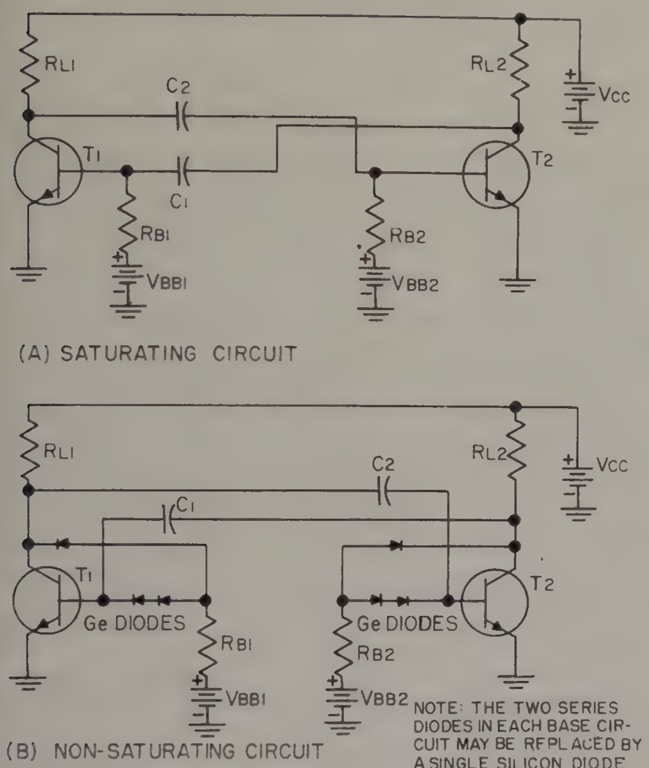


Fig. 3—Free running multivibrators.

The following inequalities result from the requirement that the transistors, when turned on, are driven to the low impedance state:

$$\beta_1 \frac{V_{BB_1}}{R_{B_1}} > \frac{V_{CC}}{R_{L1}} \quad \text{and} \quad \beta_2 \frac{V_{BB_2}}{R_{B2}} > \frac{V_{CC}}{R_{L2}} \tag{2}$$

Assuming that inequalities (1) and (2) hold, the *on* times of the transistors and the period of oscillation may be expressed as follows:

$$\text{On time for } T_1 = R_{B2}\,C_2 \ln \frac{V_{CC} + V_{BB_2}}{V_{BB_2}} \tag{3a}$$

$$\text{On time for } T_2 = R_{B1}\,C_1 \ln \frac{V_{CC} + V_{BB_1}}{V_{BB_1}} \tag{3b}$$

[2] This method of preventing saturation was developed by R. H. Baker, of M.I.T. Lincoln Laboratories

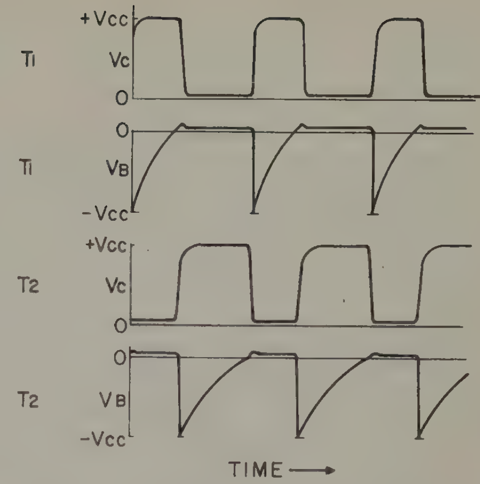


Fig. 4—Collector and base voltage waveforms in free running multivibrator.

$$\text{Period of oscillation} = R_{B1}\,C_1 \ln \frac{V_{CC} + V_{BB_1}}{V_{BB_1}} + R_{B_2}\,C_2 \ln \frac{V_{CC} + V_{BB_2}}{V_{BB_2}} \tag{3c}$$

If, as is frequently the case, the base resistors are returned to V_{CC}, then the on times and the period of oscillation become:

$$\text{On time for } T_1 = .692\,R_{B2}\,C_2 \tag{4a}$$

$$\text{On time for } T_2 = .692\,R_{B1}\,C_1 \tag{4b}$$

$$\text{Period} = .692\,(R_{B1}\,C_1 + R_{B2}\,C_2) \tag{4c}$$

If the circuit is symmetrical, $R_{B1}\,C_1 = R_{B2}\,C_2$, and the period becomes $1.384\,R_BC$.

In the circuit of *Fig. 3b*, saturation is prevented by the diodes in the collector and base circuits.[2] When one of the transistors is on, the base current flowing through the series diodes produces a voltage drop of a few tenths of a volt. When the collector junction voltage drops below the voltage across the series diodes, the diode at the collector is forward biased and tends to clamp the collector junction at a few tenths of a volt of reverse bias. The diode at the collector circuit should be of the point contact type to minimize carrier storage due to the diode. The two series germanium diodes may be replaced with a single silicon diode, as silicon diodes have a larger voltage drop when forward biased. Except for the small voltage drops due to the diodes, the circuit of *Fig. 3b* operates in the same manner as that of *Fig. 3a* and the same equations apply.

Due to the finite forward resistance of the diode in the collector circuit, it is possible for the circuit of *Fig. 3b* to be saturated if driven hard enough. It is interesting to observe that, when saturation occurs, it is frequently possible to obtain relatively high frequency oscillations once they are started. This is because at high frequencies there is not enough time for

the carrier concentration to build up to the degree necessary to stop the operation of the circuit. This, of course, has little practical value, because a multivibrator that does not start by itself but has to be shocked into oscillation would be extremely annoying. The remedy, when this effect is observed, is to go to a non-saturating circuit or, if observed in the circuit of *Fig. 3b*, to reduce the base drive by increasing the value of the base resistors.

In the expressions for the conducting periods of the transistors, it is seen that for given values of supply voltage, resistance and capacitance in the circuit the periods of conduction may be controlled by the base voltages; for example, decreasing V_{BB1} increases the on time of T_2. However, as the period is increased by decreasing the base voltage, a larger portion of the exponential rise in base voltage is used, and the base voltage approaches the switching level (slightly positive voltage) more slowly, making the circuit more susceptible to random disturbances causing jitter. For freedom from jitter, it is better to return the base resistors to a high voltage and use only a small portion of the base voltage exponential rise.

As an illustrative example, suppose that a symmetrical multivibrator having a repetition frequency of 50 kilocycles and a peak collector current of 5 milliamperes with a 6-volt supply voltage is to operate with transistors having large signal collector-base current gains greater than 30. With a 6-volt supply, the output voltage swing at the collector will be approximately 6 volts, and a 5 *ma* collector current is obtained with an R_L of 1.2 kilohms. The base resistors will be returned to the supply voltage. Thus, from inequality (2), $R_B < 30\,R_L$ or $R_B < 36K$ to get a full 6-volt collector swing with a transistor having a large signal current gain of 30. A 50 kilocycle repetition frequency corresponds to a period of oscillation of 20 microseconds ($P = 1/F$). From equation (4c) for $R_{B1}C_1 = R_{B2}C_2$, one obtains $R_BC = 20/1.384 = 14.5$ microseconds. R_B should be less than 36 kilohms, but should be much larger than R_L (from inequality (1)). Suppose R_B is chosen as 25 kilohms, then C should be 580 micro-microfarads. Since carrier storage effects can be troublesome at this frequency, the circuit of *Fig. 3b* should be used. The resulting circuit is shown in *Fig. 5*.

A one-shot multivibrator is diagrammed in *Fig. 6*. In this circuit T_1 is normally on, with a forward bias provided by R_{B1} and V_{B1}, and T_2 is normally off due to reverse bias voltage V_{BB2}. When the circuit is triggered at one of the several possible points shown, T_1 is turned off to produce a positive pulse at its collector and T_2 is turned on producing a negative pulse at its collector. The duration of the pulse is given by

$$T_d = R_{B1}\,C_1 \ln \frac{V_{CC} + V_{BB_1}}{V_{BB_1}} \qquad (5)$$

provided there is sufficient time between trigger pulses for C_1 to charge to V_{CC}.

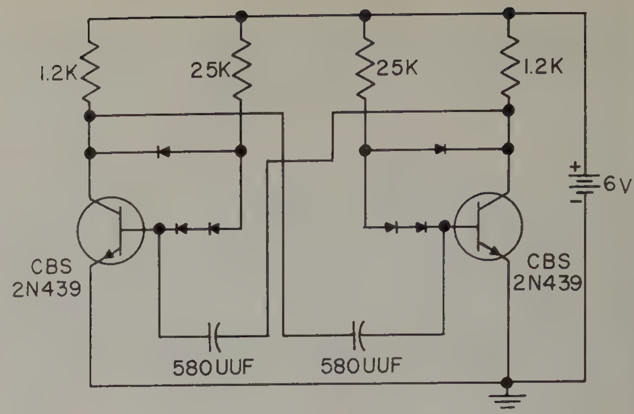


Fig. 5—50 *kc* symmetrical multivibrator.

T_1 is shown with a diode network to prevent saturation. This serves to make triggering with narrow pulses easier. T_2, which is normally off, may be allowed to saturate during the pulse interval without causing the circuit to cease functioning; for no matter how long a delay in turn off due to carrier storage, T_2 will eventually switch off. If the delay in turn off of T_2 is excessive, then T_2 may also be made nonsaturating.

When T_1 is switched off, the collector voltage rises to approximately V_{CC}, and the base of T_2 is forward biased through R_2, overcoming the reverse bias of V_{BB2}. C_2 is present only to speed up the switching transient and does not affect the pulse dimensions. R_2 should be large compared to R_{L1} to minimize loading of the collector of T_1.

The relationships between R_1, R_2 and V_{B2} are deter-

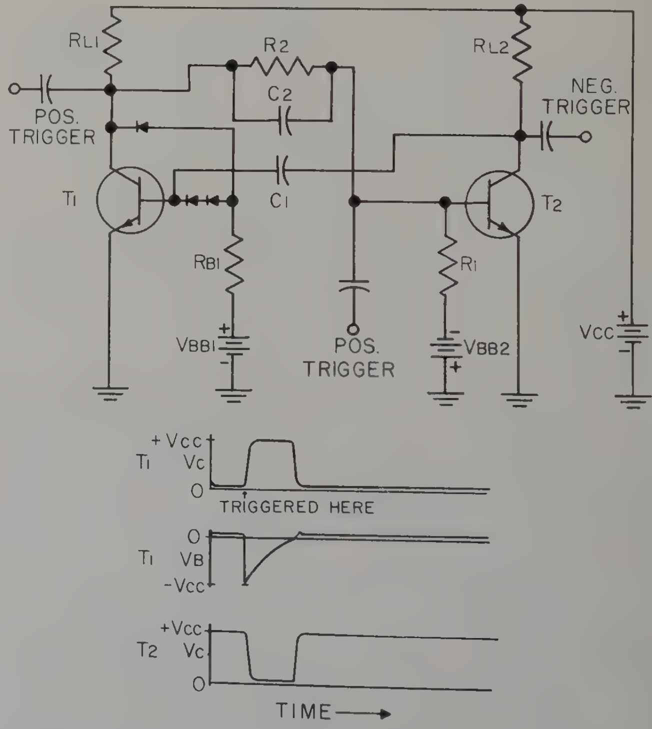


Fig. 6—One-Shot multivibrator and voltage waveforms.

mined as follows: When T_2 is off (and T_1 on), the base voltage is given by

$$\text{Off base voltage of } T_2 = \frac{-V_{BB_2} R_2}{R_1 + R_2} \tag{6}$$

The off base voltage given by (6) is a measure of the trigger required at the base of T_2 to cause the circuit to switch. For easy triggering this voltage should be low, but at the same time it should be large enough to prevent noise or spurious pulses from triggering the circuit. Its value then will depend upon the circumstances of its application.

When T_2 is on and T_1 off, the base current is given by,

$$I_{B2} = \frac{V_{CC}}{R_2} - \frac{V_{BB_2}}{R_1} \tag{7}$$

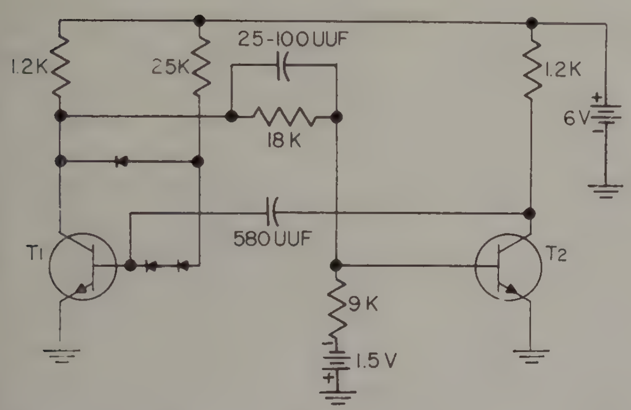


Fig. 7—One-Shot multivibrator producing 10 microsecond pulse.

where it is assumed that R_2 is much larger than R_{L1} (otherwise replace R_2 with $R_{L1} + R_2$). To fully drive

$$T_2,\ \beta I_{B2} > \frac{V_{CC}}{R_{L2}} \text{ or}$$

$$\beta\left(\frac{V_{CC}}{R_2} - \frac{V_{BB_2}}{R_1}\right) > \frac{V_{CC}}{R_{L2}} \tag{8a}$$

If $\dfrac{V_{BB_2}}{R_1} \ll \dfrac{V_{CC}}{R_2}$, then (8a) reduces to

$$R_2 < \beta R_{L2}\left(\frac{V_{BB_2}}{R_1} \ll \frac{V_{CC}}{R_2}\right) \tag{8b}$$

Equation (6) and inequality (8b) form a basis for the choice of values of R_1, R_2, and V_{BB2}. R_{B1} is determined from inequality (2).

As an example, a one-shot multivibrator producing a 10 microsecond pulse is derived. The assumption is made that the supply voltage is 6V and a 5*ma* swing in collector current is desired for both transistors. For reasons of noise immunity an off base voltage of —1 volt is to be obtained from a 1.5 volt battery for V_{BB2}. The circuit is to operate with transistors having large signal betas of greater than 30. The values of R_{B1} and

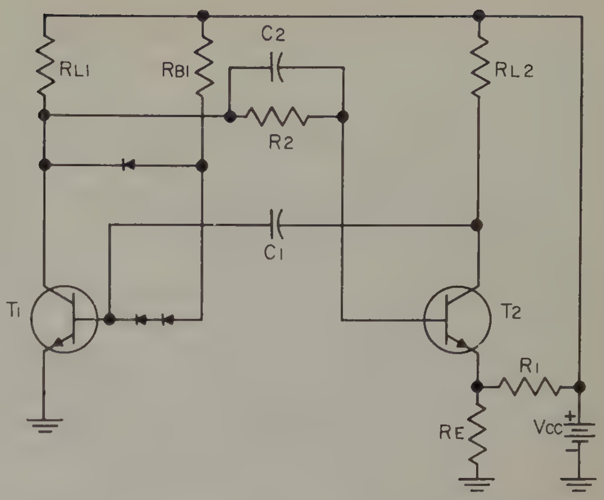


Fig. 8—One-Shot multivibrator operating from single battery.

C_1, R_{L1}, R_{L2} are exactly the same as for the 50 *kc* free-running multivibrator (where each transistor conducts for a period of 10 microseconds). There remains only the determination of R_1 and R_2. From equation (6) one has

$$-1 = \frac{-1.5\, R_2}{R_1 + R_2}$$

which may be solved for the ration of R_1 to R_2 and gives $R_1/R_2 = 0.5$. Substituting $R_1 = .5\, R_2$, $V_{CC} = 6V$, $V_{BB2} = 1.5$, $R_{L2} = 1.5K$ and $\beta = 30$ inequality (8) gives $R_2 < 18K$. Choosing R_2 as 18K (so that T_2 is fully driven for $\beta > 30$) means that R_1 should be 9K. The resulting circuit is shown in *Fig. 7*. The trigger pulse should be short compared to the width of the pulse produced (which is 10 microseconds). The value of C_2 is not critical, its presence being only to speed up the switching transient by driving T_2 hard during the initial part of its turn-on period. Typical values appropriate for C_2 might range from about 25 to 100 micro-microfarads or more for transistors having cutoff frequencies of 10 to 5 megacycles. If the circuit is to be triggered in rapid succession, C_2 should be small enough for the voltage across it to reach its quiescent value between trigger pulses.

The one-shot multivibrator may be modified to permit single battery operation as shown in *Fig. 8*. Here the emitter of T_2 is reverse biased by the voltage divider formed by R_1 and R_E. R_E should be small compared to R_{L2} and R_2. If the amount of reverse bias placed on the emitter of T_2 is small compared to the supply voltage, then R_{B1} and R_2 may be determined from inequality (2), substituting R_2 for R_{B2} and V_{CC} for V_{BB2}. The pulse duration may be determined approximately from equation (5) with V_{CC} substituted for V_{BB1}. The actual pulse width will be less than given by (5) due to the reduced swing in collector voltage of T_2 when R_E is present. This reduction in pulse width may be compensated by an increase in C_1.

[To be concluded in the next issue]

PATENT REVIEW*

Of Semiconductor Devices, Fabrication Techniques and Processes, and Circuits and Applications Sept. 25, 1951 to Sept. 9, 1952

Compiled by SIDNEY MARSHALL

The abstracts appearing in this issue cover the inventions relevant to semiconductors from September 25, 1951 to September 9, 1952. Additional items for the 1948 and 1949 compilations, which appeared in the previous issue, are also included. In subsequent issues, patents issued from September 9, 1952 to date will be presented in a similar manner. After bringing these abstracts up to date, PATENT REVIEW will appear every three months, the treatment given to each item being more detailed.

September 25, 1951

2,568,824 Semiconductor Unit For the Utilization of Electroadhesion;—K. Rahbek; Assignee: None; A Device for utilizing the electroadhesion between contacting surfaces of bodies traversable by electric current.

2,569,133 Series Capacitor Protective System;—L. Podolsky; Assignee: Sprague Electric Co.; A capacitor protecting combination including a capacitor-shunting control circuit, and a protecting circuit including a rectifier.

2,569,345 Transistor Multivibrator Circuit;—R. F. Shea; Assignee: General Electric Co., A circuit in which a square tipped voltage wave appears between the collector electrodes of a first and a second transistor, said wave having a frequency equal to one-half the frequency of a positive voltage which is applied between a voltage source and the input voltage terminal.

2,569,347 Circuit Element Utilizing Semiconductive Material;—W. Shockley; Assignee: Bell Telephone Laboratories; A solid conductive device for controlling electrical energy that comprises a body of semiconductive material having two zones of one conductivity type separated by a zone of the opposite conductivity type.

October 2, 1951

2,569,570 Crystal Diodes and Point Contact Device;—H. F. Matare, A. Poilleaux; Assignee: Compagnie des Freins et Signaux Westinghouse. A point-contact element for crystal diodes.

2,569,892 Crystal Contacts of which One Element is Mainly Silicon;—D. E. Jones, C. E. Ransley, J. W. Ryde, S. V. Williams; Assignee: Hazeltine Research Inc.; A silicon crystal element for a wave-signal translating device, said element comprising a body of highly pure silicon with a trace of aluminum and/or beryllium.

October 9, 1951

2,570,436 Crystal Controlled Oscillator;—E. V. Eberhard, R. O. Endres; Assignee: Radio Corporation of America; A crystal controlled oscillator comprising a three terminal semiconductor device.

2,570,938 Variable Reactance Transistor Circuit;—H. C. Goodrich; Assignee: Radio Corporation of America; A variable reactance circuit employing a three terminal semiconductor device and means for biasing the three electrodes in a desired manner.

2,570,939 Semiconductor Reactance Circuit —H. C. Goodrich; Assignee: Radio Corporation of America; A variable reactance system comprising a resonant circuit and having an inductive and capacitive reactance element.

2,570,978 Semiconductor Translating Device;—W. G. Pfann; Assignee: Bell Telephone Laboratories; The semiconductive body of this device has two zones of opposite conductivity type and a pair of rectifying connections, one connection to each zone.

October 16, 1951

2,571,458 Temperature Compensated Diode Measuring Circuits;—H. C. Lawrence, R. R. Freas, Jr.; Assignee: Radio Corporation of America; A device comprised of an input means, a current responsive indicator, and a diode circuit.

2,571,588 Alternating Current Rectifier of the Selenium Type;—G. H. Leland;—A selenium rectifier in which the heating of the rectifier cells is so controlled that said rectifier will operate continuously for a relatively long time without overheating said cells.

2,571,708 Reversing Magnetic Amplifier Control System;—W. L. Graves; Assignee: General Electric Co.; A reversing control system consisting of a transformer, two rectifier circuits, and two reactance windings.

October 30, 1951

2,572,993 Crystal Contact Device;—R. W. Douglass, E. G. James; Assignee: The General Electric Co. Ltd.; A crystal contact device comprising a semiconducting element sealed in a glass envelope and two metallic members making point contact with the semiconductor.

November 6, 1951

2,573,818 Alternating Current Magnetic Amplifier;—K. Votruba; Assignee (partial): Czechoslovak Metal and Engineering Works; An A. C. magnetic amplifier utilizing selenium rectifiers.

November 13, 1951

2,574,783 Rectifier Assembly;—L. K. Hedding; Assignee: Westinghouse Air Brake Co.; A rectifier assembly having a low current portion and a high current portion.

November 20, 1951

2,575,388 Electrical Rectifiers;—V. K. Kofron; Assignee: Vickers Inc.; A magnesium —selenium rectifier cell.

2,575,392 Method of Annealing a Selenium Coating;—C. E. Peters Assignee: Vickers Inc.; A method of annealing a selenium coating whereby the size of the selenium crystals become smaller and more uniform.

2,576,026 Electronic Switch;—L. A. Meacham; Assignee: Bell Telephone Laboratories; A switching network comprised of a plurality of asymmetrically conducting devices each having an electrode connected to a junction point, an input connected to one of said devices, an output connected to another of said devices, control means to the remainder of said devices, and a source of direct current connected to said junction.

November 27, 1951

2,576,267 Preparation of Germanium Rectifier Material;—J. H. Scaff, H. C. Theuerer; Assignee: Bell Telephone Laboratories: Germanium preparation by cooling a melt along an axis and removing the end of the cooled ingot.

December 4, 1951

2,577,015 Switching System;—W. R. Johnson; Assignee: Earle C. Anthony, Inc.; A switching system utilizing germanium or selenium rectifiers.

2,577,151 Regulated Rectifying Apparatus; —J. A. Potter; Assignee: Bell Telephone Laboratories; A direct current power supply with a rectifier network that incorporates selenium rectifiers.

December 11, 1951

2,577,803 Manufacture of Semiconductor Translators;—W. G. Pfann; Assignee: Bell Telephone Laboratories; A method of improving the amplification of a semiconductive translator having spaced point contacts.

December 18, 1951

2,579,336 Stabilized-Transistor Trigger Circuit;—A. J. Rack; Assignee: Bell Telephone Laboratories; An electrical trigger circuit utilizing a current multiplication three-terminal transistor and a unidirectional conducting element in series with the base electrode.

December 25, 1951

2,579,557 Counter-Electrode of Selenium Rectifiers;—T. E. Ebert; Assignee: Westinghouse Electric Corp; In a dry-type rectifier, the combination comprising a forward electrode of selenium and a counter-electrode of an alloy composed of 45%-75% tin and 55%-30% zinc.

2,579,590 Frequency Modulator;—B. E. Lenehan; Assignee: Westinghouse Electric Corporation; A frequency modulation circuit that includes a full wave rectifier, the resistance of which varies as the current passing through it.
2,580,027 Line-Contact Semiconductor Device;—H. Johnson; Assignee: Bell Telephone Laboratories; Two filamentary conductors are placed between two blocks of semiconductive material, said conductors being adjacent to one another and in intimate contact between the conductors and the semiconductive bodies.

January 1, 1952
2,581,124 Alternating Voltage Compression Network;—W. W. Moe; Assignee: Time Inc.; A circuit utilizing crystal diodes and designed to provide an electrical output that is accurately representative of the mathematical functions involved.

January 22, 1952
2,583,008 Asymmetric Electrical Conducting Device;—K. M. Olsen; Assignee: Bell Telephone Laboratories; The device is made by preparing a germanium-antimony melt in which the antimony constitutes a fraction of one percent by weight of the total, and using a copper-alloy point electrical connection.
2,583,009 Asymmetric Electrical Conducting Device;—K. M. Olsen; Assignee: Bell Telephone Laboratories; A device comprising a slab of germanium having a 0.005 per cent antimony content and utilizing a 95% pure silver-alloy contact point.

January 29, 1952
2,583,681 Crystal Contacts of which One Element is Silicon;—F. H. Brittain, C. E. Ransley, J. W. Ryde; Assignee: Hazeltine Research Inc.; The method of manufacturing consists of polishing the contact surface of the silicon, etching it with hydrofluoric acid in order to form an oxide layer, and etching the surface a second time to remove most of the oxide.

February 5, 1952
2,584,461 Electrical Crystal Contact Device;—E. G. James, A. O. Lindell; Assignee: Hazeltine Research Inc.; A device comprising a tapered semiconducting crystal-contact element, a metallic contact element with a sharp edge conditioned to engage the tapered portion, a means for supporting the elements, a means for adjustment during assembly, and a means of insuring point contact between the sharp edge and the tapered portion.

February 12, 1952
2,584,990 Transistor Counting System;—T. L. Dimond; Assignee: Bell Telephone Laboratories; The system is composed of a device for counting a definite number of operations, storing and charging condensers, a fixed voltage supply, and a three-terminal transistor.

February 12, 1952
2,585,077 Control of Impedance of Semiconductor Amplifier Circuits;—H. L. Barney; Assignee: Bell Telephone Labs; In an amplifier network a transistor, means for establishing proper bias conditions, an input circuit connecting the base and the emitter electrodes, an output circuit connecting the emitter and the collector electrodes, and a load; said output circuit having a value of effective resistance such as to cause the input impedance of the network to have a desired value.

2,585,078 Negative Resistance Device Utilizing Semiconductor Amplifier;—H. L. Barney; Assignee: Bell Telephone Laboratories; A device for which the transistor parameters are determined by:

$$r_m > r_e + r_c + \frac{r_e r_c}{r_b} \quad \text{where}$$

r_e=emitter resistance
r_c=collector resistance
r_b=base resistance
r_m=mutual resistance

February 19, 1952
2,586,080 Semiconductive Signal Translating Device;—W. G. Pfann; Assignee: Bell Telephone Laboratories; An amplifier comprising a body of n-type germanium having in one face thereof spaced zones of p-type germanium, a row of point contacts and a group of contacts that alternately touch the n-type and p-type material.
2,586,539 Metal Rectifier Assembly;—E. A. Harty; Assignee: General Electric Corporation; A self contained selenium rectifier cell utilizing a plate-shaped base electrode.

February 19, 1952
2,586,597 Oscillation Generator;—J. Bardeen, W. H. Brattain; Assignee: Bell Telephone Laboratories; A device consisting of a block of semi-conductive material of which the body is one conductivity type and a thin surface layer, separated from the body by a high resistance barrier of the opposite conductivity type; two point-contact electrodes, a base electrode and means for feeding back energy from a work circuit to the input circuit to sustain self-oscillations.
2,586,609 Point-Contact Electrical Device;—E. W. Burke, Jr. Assignee: Sylvania Electric Products Inc.; A semiconductor device including a semiconductor element and a point-contact element both embedded in a body of solidified polymer, said semiconductor body and its contact being joined to spaced leads banded to the polymer and extending therethrough to points of emergence.

March 4, 1952
2,588,008 Germanium Crystal Rectifiers and Method of Producing the Crystal Element Thereof;—D. E. Jones, J. W. Ryde; Assignee: Hazeltine Research Inc.; The method of producing a crystal rectifier by shaping a body of high purity germanium to form a crystallographic cleavage contact surface on said body and subsequently etching the contact surface.
2,588,253 Alloys and Rectifiers made Thereof;—K. Lark-Horovitz, R. M. Whaley; Assignee: Purdue Research Foundation; A rectifying device made from 99% pure germanium and a trace of at least one element from the copper-silver group, said rectifier having a peak back voltage between 10 volts and 200 volts.
2,588,254 Photoelectric and Thermoelectric Device Utilizing Semi-conducting Material;—K. Lark-Horovitz, S. Benzer, R. E. Davis; Assignee: Purdue Research Foundation; A device comprising a single body of germanium having several alternate regions of n-type and p-type conductivity.

March 11, 1952
2,588,806 Alternating Current Rectifier of the Dry Surface Contact Type;—R. H. Cubitt, R. G. Sell; Assignee: Westinghouse Air Brake Co.; A hermetically sealed rectifier assembly containing two rectifying elements.
2,588,956 Crystal Rectifier;—F. H. Brattain, E. G. James; Assignee: The General Electric Co. Ltd.; A crystal rectifier consisting of an encapsulated semiconducting crystal and a metal whisker which presses resiliently against the crystal surface.

March 18, 1952
2,589,658 Semiconductor Amplifier and Electrode Structures Therefore;—J. Bardeen; Assignee: Bell Telephone Laboratories: A three terminal semiconductive device with one electrode symmetrically disposed about another electrode.
2,589,704 Semiconductor Signal Translating Device;—W. E. Kirkpatrick, R. W. Sears; Assignee: Bell Telephone Laboratories; A semiconductive body having an ohmic base connected thereto, a rectifying connection to said body, and a means of directing an electron beam against the body in proximity to the rectifying connection.

April 8, 1952
2,591,961 Transistor Ring Counter;—R. P. Moore, Jr., E. Eberhard; Assignee: Radio Corporation of America; A ring counter having several counter stages connected in a closed loop, each stage having a non-indicating, a primed, and an indicating condition.
2,592,257 Hall Effect Device;—W. C. Dunlap, Jr.; Assignee: General Electric Co.; A Hall effect device comprising a Hall plate, input electrodes, output electrodes, and an elongated conductor having a diameter less than the thickness of the Hall plate for producing a magnetic field perpendicular to the plane of said plate when a current is passed through the conductor.

April 15, 1952
2,592,683 Storage Device Utilizing Semiconductor;—F. Gray; Assignee: Bell Telephone Laboratories; The resistance of the metallic electrode that makes contact with the semiconductor is sensitive to the presence of electric charge.

April 29, 1952
2,594,336 Electrical Counter Circuit;—M. E. Mohr; Assignee: Bell Telephone Laboratories; A circuit including a plurality of variable resistance elements each having a characteristic including a predetermined range of quantities within which either of two stable states prevails for a given operating condition.
2,594,449 Transistor Switching Device;—R. J. Kircher; Assignee: Bell Telephone Laboratories; A sampling circuit which comprises a signal source, a signal utilization circuit, and two transistors.
2,595,052 Crystal Amplifier;—E. T. Casellini; Assignee: Sylvania Electric Products Inc.; Unit consists of a semiconducting crystal, a metallic mesh grid on the surface of the crystal, and catwhisker contacts to the crystal.
2,595,208 Transistor Pulse Divider;—J. T. Bangert; Assignee: Bell Telephone Laboratories; An electrical trigger circuit utilizing a three terminal transistor that is characterized by a ratio of short circuit collector current to emitter current greater than unity for a specified range, said circuit having been designed to respond to voltage impulses of the same polarity applied to a single set of input terminals.

May 6, 1952
2,595,232 Telephone Switching System Employing a Transistor;—P. L. Dimond; Assignee: Bell Telephone Laboratories; In a telephone system, a plurality of subscribers lines; a semiconducting device including a plurality of emitter elec-

trodes engaging a base member; means for supplying voltage to said emitters under control of the line individual thereto; and means, connected in a circuit with the collector, responsive to a call from a subscriber line.

2,595,475 Electrode Support for Semiconductor Devices;—K. M. McLaughlin; Assignee: Radio Corporation of America; A device designed to present a crystal support that maintains a permanent alignment of the crystal with respect to the electrodes; to avoid close tolerances or matching parts; and to permit adjustment of the position of the crystal with respect to the point electrodes in order to provide the desired contact pressure before the parts are rigidly fastened.

2,595,496 Cascade-Connected Semiconductor Amplifier;—W. M. Webster, Jr.; Assignee: Radio Corporation of America; an amplifier designed to have a high power gain and a much higher voltage gain than the combined voltage gain of the individual stages; to provide a device in which the input impedance of the first stage is of the same order as the output impedance of the last stage; and to present a three-electrode semiconductor amplifier as an impedance matching device for another amplifier.

2,595,497 Semiconductor Device for Two-Stage Amplifiers;—W. M. Webster, Jr.; Assignee: Radio Corporation of America; A device comprising a single semiconducting body of substantially uniform characteristics having a bifurcated base and individual electrodes to the separate surface areas of the base.

2,595,780 Method of Producing Germanium Pellets;—W. C. Dunlap; Assignee: General Electric Company; The method consists of placing a germanium ingot in a crucible that has a small hole at the bottom, and heating the ingot above its melting point while in the presence of a gas inactive to germanium, the latter step causing molten droplets of germanium to be blown out of the hole.

May 20, 1952

2,597,000 Metal Rectifier Bridge;—G. G. Hyde; Assignee: Federal Telephone and Radio Corp.; A selenium rectifier bridge having four metal rectifier elements each having a conducting face and an opposite conducting face, said elements being arranged to form a rectifier bridge.

2,597,028 Semiconductor Signal Translating Device;—W. G. Pfann; Assignee: Bell Telephone Laboratories; The device consists of a body of semiconductive material having within it a limited zone of which the conductivity is different from that of the remainder of the body, and a base, emitter, and collector electrode.

2,597,734 Electric Crystal-Contact Device;—E. G. James, A. O. Lindell; Assignee: Hazeltine Research Inc.; A device designed to provide an electrical crystal contact that has accurate spacing between the contact points engaging the semiconducting crystal.

June 3, 1952

2,599,478 Apparatus For Making Devices Which Have Selenium As Constituent Parts Thereof;—C. E. Peters, D. W. Rau, A. H. Bruemmer; Assignee: Vickers Inc.; A machine for applying selenium to base plates, said machine utilizing means for providing advancements of uniform length and rests of uniform duration.

June 10, 1952

2,600,373 Semiconductor Translating Device;—A. R. Moore; Assignee: Radio Corporation of America; A system comprising a means for developing an electron beam and directing it to impinge on a semiconductive body in the vicinity of a rectifying electrode.

June 17, 1951

2,600,500 Semiconductor Signal Translating Device with Controlled Carrier Transit Times;— J. R. Haynes, W. Shockley; Assignee: Bell Telephone Laboratories; A device comprised of a semiconductive body having an elongated portion, a base connection, an input circuit, a means for injecting charges of one polarity into the body, an output circuit and means for applying a potential which will cause the charges to accelerate.

2,600,997 Alloys and Rectifiers Made Thereof;—K. Lark-Horovitz, R. M. Whaley; Assignee: Purdue Research Foundation; A point contact semiconductor device composed of 99% pure germanium with the remainder taken from the group consisting of vanadium, colombium, tantalum, and bismuth, said device having a peak back voltage between 10 volts and 200 volts.

July 8, 1952

2,602,211 Rectifier and Method of Making It;—J. H. Scaff, H. C. Theuerer; Assignee: Bell Telephone Laboratories; The method involves preparing a germanium melt containing a trace of an impurity taken from the odd series of the fifth period of the periodic table, in an oxygen-free atmosphere, and cooling the melt to form an ingot having zones of differing electrical polarity.

2,602,763 Preparation of Semiconductive Materials for Translating Devices;—J. H. Scaff, H. C. Theuerer; Assignee: Bell Telephone Laboratories; A method of producing germanium which comprises heating a germanium alloy at a series of temperatures between 400°C and 900°C and measuring the resistivity following each heating, further heating said alloy at a selected temperature in said range and cooling to make an alloy of the prescribed conductivity type.

July 15, 1952

2,603,692 Rectifier and Method of Making It;—J. H. Scaff, H. C. Theuerer; Assignee: Bell Telephone Laboratories; A point contact semiconducting rectifying device encased in a housing of low dielectric constant insulating material.

2,603,693 Semiconductor Signal Translating Device;—R. J. Kircher; Assignee: Bell Telephone Laboratories; A semiconductive body having at one portion thereof, a region containing a greater concentration of impurity than the bulk of said body.

2,603,694 Semiconductor Signal Translating Device; R. J. Kircher; Assignee: Bell Telephone Laboratories; A device consisting of a semiconductive body of one conductivity-type, a means of defining a barrier to the flow of charge carriers of sign opposite to those normally found in the body said means comprising contiguous zones of like conductivity-type but of different conductivity.

July 22, 1952

2,604,496 Semiconductor Relay Device;—L. P. Hunter; Assignee: Westinghouse Electric Corp.; A relay device comprising a block of n-type semiconductive material having a small p-type inclusion on its face, said device having been designed to be triggered by either a positive or negative pulse or by thermal action, without changing the polarity of the circuit parameters.

2,605,306 Semiconductor Multivibrator Circuit—E. Eberhard; Assignee: Radio Corporation of America; A monostable multivibrator circuit utilizing two three-terminal semiconductor devices.

July 29, 1952

2,605,302 Direct Current Measuring Apparatus;—T. R. Specht; Assignee: Westinghouse Electric Corporation; An induction system for measuring direct current comprising a pair of magnetizable core members, direct current conducting means, a pair of A.C. windings, and a dry-contact rectifier circuit.

August 12, 1952

2,606,405 Polishing Means and Method;—R. S. Ohl; Assignee: Bell Telephone Laboratories; A method of polishing a crystalline material of the nature of highly pure crystalline silicon.

2,606,960 Semiconductor Translating Device;—J. B. Little; Assignee: Bell Telephone Laboratories; A device consisting of a pair of critically spaced wire contacts embedded in a plane-faced insulating block which in turn is brought into contact with the plane face of a semiconductive body.

August 26, 1952

2,608,611 Selenium Rectifier Including Tellurium and Method of Making It;—J. N. Shive; Assignee: Bell Telephone Laboratories; An asymmetric conducting device comprising a backing electrode, a thin layer of tellurium thereon, a selenium layer on the tellurium layer, and a front electrode contacting the selenium layer.

2,608,679 Static Network;—R. L. Witzke; Assignee: Westinghouse Electric Corp.; The network, designed to prevent the field excitation of a generator from being reduced below the stable limit, is composed of an output-responsive measuring network and several dry-contact rectifier arrangements.

September 2, 1952

2,609,427 Three-Electrode Semiconductor Device;—J. P. Stelmark; Assignee: Radio Corporation of America; The device is designed to permit higher than normal contact pressure between the semiconductor and its small area electrodes, thus decreasing the noise due to a variation in contact pressure; in addition the device is designed to have improved mechanical stability and electrical characteristics.

2,609,428 Base Electrode For Semiconductor Devices;—H. B. Law; Assignee: Radio Corporation of America; The base electrode of this device has a contact resistance which is lower than that of the other electrodes; by virtue of this fact it controls the potential of the bulk of the semiconductive body.

2,609,429 Semiconduction Electrode Construction;—H. B. Law; Assignee: Radio Corporation of America; A semiconductor device having two surfaces intersecting in an angle, two electrodes making point contact with each intersecting face, and an insulating member having an aperture through which the two point-contact electrodes pass.

September 9, 1952

2,610,234 Crystal Triode;—A. H. Dickinson; Assignee: International Business Machines Corp.; A crystal triode with low output impedance having a collector electrode which makes continuous live contact with one face of the crystal.

SEMICONDUCTOR & SOLID-STATE BIBLIOGRAPHY

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
Protection of Sensitive Current Devices with Silicon Diodes	Control Engineering July 1958	Forward characteristics of silicon diodes and reverse characteristics of silicon Zener diodes, make these devices suitable for the job.	P. L. Toback
Microwave Applications of Thermistors Part 2	Electronic Design July 23, 1958	Waveguide thermistor mounts, impedance matching, and *r-f* power measurements are discussed.	L. I. Kent
Rectifier Power Nomogram	Electronic Design July 23, 1958	Relates power dissipation, average rectified current into a resistive load, and dynamic resistance.	J. S. Gillette W. B. Mitchell
Reducing Standby Current with Silicon Diodes	Electronic Design July 23, 1958	Stabilization of transistor circuits with auxilary diodes.	T. P. Sylvan
Rectifiers in high voltage Power Supplies	Electronic Design July 23, 1958	Practical considerations of rectifier characteristics in design and applications.	F. W. Gutzwiller
With Zener Diodes the Curves Make all the Difference	Electronic Design July 23, 1958	Discussion of Zener characteristics and their significance in design work.	B. B. Daien
Choosing Diodes for Typical pulse Systems	Electronic Design July 23, 1958	Guide to proper selection of diode types in a particular system.	F. C. Jarvis
Diode Packages and Junctions	Electronic Design July 23, 1958	Review of diode encapsulations, junction constructions, typical applications.	J. S. Gillette W. B. Mitchell
The Measurements of Transistor Voltage-Current Characteristics using pulse Techniques	Electronic Engineering (Brit.) July 1958	Gives ambient temperature characteristics, reduces effect of junction heating and thermal runaway.	B. J. Cooper
A Sensitive Defocusing Photo-Electric Pressure Transducer	Electronic Engineering (Brit.) July 1958	Symmetrical output of over 20V may be obtained for pressure differences of a few *cm* of water.	J. R. Green
The Physical Interpretation of Mean Free Path and the Integral Method	IBM Journal of Research and Development July 1958	Explanation of the "vector mean free path" construct to which physical interpretation leads.	P. J. Price
A Full Binary Adder Employing Two Negative-Resistance Diodes	IBM Journal of Research and Development July 1958	Adder described employs Reeves-Cooke positive-gap diodes which operate with pulses of 20-millieusec duration.	J. W. Horton A. G. Anderson
Transistorized Sound Section for TV Receivers	IRE Transactions on Broadcast and TV Receivers June 1958	Two circuits for transistorized sound sections for use in hybrid or all-transistor TV receivers are described.	G. Schiess W. Palmer
Transistorized TV Horizontal Deflection and High Voltage Systems	IRE Transactions on Broadcast and TV Receivers June 1958	Design considerations for transistorized television horizontal-deflection circuits are given.	G. Schiess W. Palmer
Characteristics and Applications of Low Impedance Diodes Used as Voltage Variable Capacitors	IRE Transactions on Broadcast and TV Receivers June 1958	Data concerning the variation of diode capacitance with bias voltage is presented and circuit requirements for resonant circuits tuned with *v-c* diodes are discussed.	W. F. Palmer D. H. Rice
Evaluation of Transistor Neutralization Networks	IRE Transactions on Circuit Theory June 1958	Method by which most neutralizing circuits can be evaluated. Frequencies covered are 200 *kc* to 80 *mc*.	A. J. Cote, Jr.
Transient Response of Phosphor	IRE Transactions on Component Parts June 1958	Analysis of buildup and decay shows that under certain conditions the transient behavior can be accurately expressed in relatively simple form.	G. I. Cohn H. M. Musal
Conductive Ceramics	IRE Transactions on Component Parts June 1958	Description of a representative selection of conductive ceramic materials, with a table of physical, thermal and electrical properties.	Z. A. Post P. E. Ritt
Recent Advances in the Solid-State Electrolytic Capacitor	IRE Transactions on Component Parts June 1958	A model has been proposed which serves to explain four sets of apparently unrelated electrical characteristics of the unit operating at 100V *d-c* and 150°C.	A. V. Fraioli
Nonlinear Transfer Functions with Thyrite	IRE Transactions on Electronic Computers June 1958	Circuit configurations which provide cosine and sine functions are given.	L D. Kovach W. Comley
Analytical Design of Resistor-Coupled Transistor Logical Circuits	IRE Transactions on Electronic Computers June 1958	Analysis of design procedures for circuit used in the mechanization of logical operations.	M. W. Marcovitz E. Seif
A Multidecade Logarithmic Sweep	IRE Transactions on Instrumentation June 1958	Design procedure. Addition of exponential functions by means of a transistor feedback amplifier.	R. W. Archbald J. P. McNeill E. Schutzman

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
Further Progress in Electronic Control of Artificial Respiration	IRE Transactions on Medical Electronics July 1958	Use of electronic amplifiers (using transistors) in conjunction with other instrumentation as supportive devices in cases of muscle failure.	L. H. Montgomery S. E. Stephenson, Jr.
Solid-State Dissolution of Germanium by Indium in Semiconductor Devices	Journal of Applied Physics June 1958	Effects of physical variables on the formation of solution cavities in SBT's and germanium are discussed.	J. Roschen C. G. Thornton
Electrical Contacts to Silicon Carbide	Journal of Applied Physics June 1958	Nonrectifying contacts may be made using silicon-phosphorous alloys.	R. N. Hall
Effect of Dislocations on Breakdown in Silicon *p-n* Junctions	Journal of Applied Physics July 1958	Breakdown effects have been compared with etch-pit patterns that reveal dislocations.	A. G. Chynoweth G. L. Pearson
Space Charge Calculations for Semiconductors	Journal of Applied Physics July 1958	General equation relating electric field to the electrostatic potential difference.	R. Seiwatz M. Green
Dislocations and Selective Etch Pits in InSb	Journal of Applied Physics July 1958	Dislocation etch pit illustrates polarity of structure and nature of dislocations.	V. D. Venables R. M. Broudy
Dislocation Etch Pits in Antimony	Journal of Applied Physics July 1958	Effects of various etching reagents on producing different types of etch pits.	J. H. Wernick J. N. Hobstetter L. C. Lovell D. Dorsi
Photoconductivity	Journal of Applied Physics (Brit) June 1958	Basic factors are discussed with general pattern of behavior to be expected indicated.	D. A. Wright
Thermionic and Related Properties of Calcium Oxide	Journal of Applied Physics (Brit) July, 1958	Changes in thermionic emission and conductivity have been found during activation and poisoning.	B. J. Hopkins F. A. Vick
The Performance of Infra-Red Photoconductive Cells	Journal of Applied Physics (Brit) July, 1958	Responsivity and signal/noise ratio under various conditions of noise limitation.	D. H. Roberts B. L. H. Wilson
Electropolishing Silicon in Hydrofluoric Acid Solutions	Journal of the Electrochemical Society July 1958	Experimental results on the effect of HF concentration, viscosity and temperature.	D. R. Turner
Melted Layer Crystal Growth and its Application to Germanium	Journal of the Electrochemical Society July 1958	Data given for resistivity profiles of germanium crystals doped with antimony.	F. H. Horn
Power Amplification X Bandwidth Figure of Merit for Transducers Including Transistors	Journal of Electronics and Control (Brit) June 1958	The figure of merit is derived for a transducer which is unilateralized and conjugately matched.	L. J. Giacoletto
The Avalanche Breakdown Voltage of Narrow p^t ν n^t Diodes	Journal of Electronics and Control (Brit) June 1958	The extension of the space-charge region does not immediately lead to a rapid increase of current with applied voltage.	J. Shields
Carrier Mobilities in InP, Ga, As, and AlSb	Journal of Electronics and Control (Brit) July 1958	Measurements have been mads as functions of impurity concentration and temperature.	F. J. Reid R. K. Willardson
Dislocation Etch Pits in Germanium	Journal of Electronics and Control (Brit) July 1958	The influence of the direction of the dislocation line on the shape of the etch pits is examined.	W. Bardsley R. L. Bell B. W. Straughan
Recombinaison Sur les Pieges a deux niveaux dans les Semi-Conducteurs	Journal of Electronics and Control (Brit) July 1958	Derivation of the recombination statistics of excess carriers in Semiconductors through a Hall-Shockley-Read mechanism is given.	M. Bernard
Analysis of Current Flow in a Planar Junction Diode at a High Forward Bias.	Journal of Electronics and Control (Brit) July 1958	Analysis is concerned with the general case of an asymmetric diode, the impurity concentrations and widths of both sides being arbitrary.	A. K. Jonscher
Paramagnetic Resonance	Philips Technical Review May 31, 1958	Discussion of quantum-mechanical background. Description of setup for observing resonance spectrum.	J. S. Van Wieringen
Photoconductivity of Zinc Selenide Crystals and a Correlation of Donor and Acceptor Levels in II-VI Photoconductors	Physical Review June 1, 1958	By a consideration of known data on the conductivity, photoconductivity, and luminescence of II-VI compounds, a consistent correlation of donor and acceptor levels in these materials is possible.	R. H. Bube E. L. Lind
Magnetoresistance Symmetry Relation in *n*-Germanium	Physical Review June 1, 1958	A relationship is obeyed for samples with carrier concentration as high as 6 X 10^{15} cm $^{-3}$	C. Goldberg W. E. Howard
Magnetic Properties of *n*-Type Silicon	Physical Review June 1, 1958	The magnetic susceptibility has been measured as a function of temperature from 3°K to 300°K	E. Sonder D. K. Stevens
Variation of Hall Mobility of Carriers in Nondegenerate Semiconductors With Electric Field	Physical Review June 15, 1958	Expression for Hall mobility is obtained applicable in a large range of fields and non-Maxwellian distribution of velocities of carriers.	M. S. Sodka P. C. Eastman
Lifetime in P-type Silicon	Physical Review June 15, 1958	Lifetime is measured as a function of excess election density	J. S. Blakemore

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
Electron-Bombardment Damage in Silicon	Physical Review June 15, 1958	Damage is investigated by using Hall effect, conductivity, and carrier-lifetime measurement.	G. K. Wertheim
Magneto-Surface Experiments on Germanium	Physical Review June 15, 1958	Ambient-induced changes in the conductivity, Hall coefficient, and magnetoresistance.	J. N. Zemel R. L. Petritz
Theory of an Experiment for Measuring the Mobility and Density of Carriers in the Space-Charge Region of a Semiconductor Surface	Physical Review June 15, 1958	The use of galvanomagnetic experiments to determine the mobility and density of carriers in the space-charge region of a semiconductor surface is considered.	R. L. Petritz
Electrical Conduction via Slow Surface States on Semiconductors	Physical Review July 1, 1958	Steady-state and transient conductance of inversion layers were investigated.	H. Statz G. A. deMars
Effective Mass of Electrons in Gallium Arsenide	Physical Review July 1, 1958	Measurement has been made by determining the reflectivity in the infrared.	L. C. Barcus A. Perlmutter J. Callaway
Large-Signal Surface Photovoltage Studies with Germanium	Physical Review July 1, 1958	Studies cover a wider range of excess carrier densities than previously reported.	E. O. Johnson
Mobility of Electrons in Germanium-Silicon Alloys	Physical Review July 1, 1958	Compositions vary between 0 to 30 atomic percent silicon; temperature range between 77°K and 300°K.	M. Glicksman
Measurement of Germanium Surface States by Pulsed Channel Effect	Physical Review July 1, 1958	Densities, cross sections, and activation energies are inferred from conductivity relaxations.	G. Ruffrecht
Interpretation of Magneto conductivity in n-type Germanium and Silicon	Physical Review July 1, 1958	Low-field magnetoconductivity with no assumptions about the scattering process.	R. W. Keyes
Phonon-Drag Thermo-magnetic Effects in n-type Germanium. I-General Survey	Physical Review July 1, 1958	Basic ideas of the theory; central experimental results; qualitative conclusions.	C. Herring T. H. Geballe J. E. Kunzler
Optical Absorption in p-type Gallium Arsenide	Physical Review July 12, 1958	A number of absorption bands have been observed on the low-energy side of the intrinsic absorption edge.	R. Braunstein L. Maged
Electrical Properties of Mercury Telluride	Physical Review July 15, 1958	HgTe was found to be p-type with acceptor concentration of 10^{18}—10^{19} cm^{-3} and band gap $\sim$ .02 ev.	R. O. Carlson
Temperature Dependence of Optical Absorption in p-Type Indium Arsenide	Physical Review July 15, 1958	Energy shifts to lower values at lower temperatures and to a stationary value above 420°K.	F. Matossi F. Stern
Intrinsic Optical Absorption in Single-Crystal Silicon Carbide	Physical Review July 15, 1958	Results of measurment in both the cubic and hexagonal, type 6H, modification.	H. R. Philipp
Radiation Damage in GE and Si Detected by Lifetime Changes: Damage Thresholds	Physical Review July 15, 1958	Minority carrier lifetime is shown to be more sensitive to radiation than the conductivity.	J. J. Loferski P. Rappaport
Certain Characteristics of Noise in CdS Photoresistors (Excerpts)	Radiotekhnica i Electronika (USSR) March 1958. Eng. Trans: Electronics Express June 1958	A study is made of the dependence of the noise current on the amount and quality of the incident exciting emission, and on the applied voltage.	S. V. Svechnikov V. I. Dvortsin
The Noise Spectrum and Frequency Characteristics for Photocurrent in Thallous Sulphite Photoresistors (Excerpts)	Radiotekhnica i Electronika March 1958. English Trans: Electronics Express June 1958	Description and results of measurements. For small values of light flux ($\sim 10^{-9}$ lum) a similarity has been detected between these two characteristics.	L. Ia. Pervova
A Unit for Measuring the Hall Effect in Semiconductors (complete)	Technical Physical Journal (USSR) No. 26-1957, Eng. Trans: Electronics Express March 1958	Method employing an a-c current and an a-c magnetic field in which the Hall Effect is measured at the sum or difference frequency is described.	V. N. Bogomolov V. A. Miasnikov
Method of Measuring the Rate of Surface Recombination According to the Variation of the Resistance of a Semiconductor in a Magnetic Field X (Excerpts)	Technical Physical Journal (USSR) June 1957. English Trans: Electronics Express March 1958	The basis of this method is the dependence of the resistance of a thin semiconductor on the recombination rates on its faces, in a magnetic field.	V. P. Zhuze G. E. Pikus O. V. Sorokin
On the Equivalent Circuits of Linear Amplifiers	U.S. Gov't Research Report PB127233 7/11/58	Reciprocal forward-and reverse-equivalent circuits are derived. Applications to transistor amplifiers shown.	L. M. Vallese
Investigation of Germanium-Silicon Alloys	U.S. Gov't Research Report PB131422 7/11/58	The isothermal solidification techniques used in preparing these alloys is described in detail.	C. C. Wang

CHARACTERISTICS CHART

of

SISICON ZENER or AVALANCHE DIODES

MOT—Motorola, Inc.
NAE —North American Electronics
PSI —Pacific Semiconductors
TI —Texas Instruments
TRA—Transitron Electronic Corp.
USS —U. S. Semiconductor Products

TYPE NO.	Zener or Avalanche Voltage Range			Dynamic Impedance		MAX. DISS.	TEMP. CO-EF-FICIENT	MFR. (See code at start of chart)
	MIN. E_{b1} (volts)	MAX. E_{b2} (volts)	@ I_z (ma)	Z @ I_z (ohms)	(ma)	(mw)	%/°C	
1N747	3.24	3.96	20	22	20	400	.055	TI
1N748	3.51	4.29	20	20	20	400	.049	TI
1N749	3.87	4.73	20	19	20	400	.036	TI
1N750	4.23	5.17	20	17	20	400	.018	TI
1N751	4.59	5.61	20	16	20	400	.008	TI
1N752	5.04	6.16	20	11	20	400	.006	TI
1N753	5.56	6.82	20	7	20	400	.022	TI
1N754	6.12	7.48	20	5	20	400	.035	TI
1N755	6.75	8.25	20	6	20	400	.045	TI
1N756	7.38	9.02	20	8	20	400	.052	TI
1N757	8.19	10.01	20	10	20	400	.056	TI
1N758	9.0	11.0	20	12	20	400	.060	TI
1N1816	11.7	14.3	500	2	500	10	.07	TI
1N1817	14.5	16.5	500	2	500	10	.07	TI
1N1818	14.4	17.6	500	3	500	10	.07	TI
1N1819	16.2	19.8	500	3	500	10	.07	TI
1N1820	18.0	22.0	150	3	150	10	.08	TI
1N1821	19.8	24.2	150	3	150	10	.08	TI
1N1822	21.6	26.4	150	3	150	10	.08	TI
1N1823	24.3	29.7	150	3	150	10	.08	TI
1N1824	27.0	33.0	150	4	150	10	.08	TI
1N1825	29.7	36.3	150	4	150	10	.08	TI
1N1826	32.6	39.6	150	5	150	10	.09	TI
1N1827	35.1	42.9	150	5	150	10	.09	TI
1N1828	38.7	47.3	150	6	150	10	.09	TI
1N1829	42.3	51.7	150	7	150	10	.09	TI
1N1830	45.9	56.1	150	8	150	10	.10	TI
1N1831	50.4	61.6	150	9	150	10	.10	TI
1N1832	55.8	68.2	50	12	50	10	.10	TI
1N1833	61.2	74.8	50	14	50	10	.10	TI
1N1834	67.5	82.5	50	20	50	10	.11	TI
1N1835	73.8	90.2	50	22	50	10	.11	TI
1N1836	81.9	100.1	50	35	50	10	.12	TI
1N1875	7.5	9.1	50	1	50	3W	.04	USS
1N1876	9.1	11	50	1.3	50	3W	.058	USS
1N1877	11	13	50	1.8	50	3W	.059	USS
1N1878	13	16	50	2.0	50	3W	.060	USS
1N1879	16	20	50	2.6	50	3W	.062	USS
1N1880	20	24	15	10	15	3W	.064	USS
1N1881	24	30	15	18	15	3W	.066	USS
1N1882	30	36	15	24	15	3W	.068	USS
1N1883	36	43	15	26	15	3W	.07	USS
1N1884	43	51	15	28	15	3W	.072	USS
1N1885	51	62	15	30	15	3W	.075	USS
1N1886	62	75	7.5	35	7.5	3W	.08	USS
1N1887	75	91	7.5	45	7.5	3W	.086	USS
1N1888	91	110	7.5	60	7.5	3W	.093	USS
1N1889	110	130	7.5	85	7.5	3W	.10	USS
1N1890	130	160	7.5	110	7.5	3W	.12	USS
1N1891	7.5	9.1	50	1	50	10W	.04	USS
1N1892	9.1	11	50	1.3	50	10W	.058	USS
1N1893	11	13	50	1.8	50	10W	.059	USS
1N1894	13	16	50	2.0	50	10W	.060	USS
1N1895	16	20	50	2.6	50	10W	.062	USS
1N1896	20	24	15	10	15	10W	.064	USS
1N1897	24	30	15	18	15	10W	.066	USS
1N1898	30	36	15	24	15	10W	.068	USS
1N1899	36	43	15	26	15	10W	.07	USS
1N1900	43	51	15	28	15	10W	.072	USS
1N1901	51	62	15	30	15	10W	.075	USS
1N1902	62	75	7.5	35	7.5	10W	.08	USS
1N1903	75	91	7.5	45	7.5	10W	.086	USS
1N1904	91	110	7.5	60	7.5	10W	.093	USS
1N1905	110	130	7.5	85	7.5	10W	.10	USS
1N1906	130	160	7.5	110	7.5	10W	.12	USS
1N1927	3.6	4.3	5	11	10	200	.06	USS
1N1928	4.3	5.1	5	10	10	200	.05	USS
1N1929	5.1	6.2	5	8	10	200	.01	USS
1N1930	6.2	7.5	5	7	10	200	.03	USS
1N1931	7.5	9.1	5	15	10	200	.06	USS
1N1932	9.1	11.0	5	22	10	200	.065	USS

TYPE NO.	Zener or Avalanche Voltage Range MIN. E_{b1} (volts)	MAX. E_{b2} (volts)	@ I_z (ma)	Dynamic Impedance Z @ I_z (ohms)	(ma)	MAX. DISS. (mw)	TEMP. CO-EF-FICIENT %/°C	MFR. (See code at start of chart)
1N1933	11	13	1	30	5	200	.08	USS
1N1934	13	16	1	50	5	200	.088	USS
1N1935	16	20	1	70	5	200	.092	USS
1N1936	20	24	1	100	5	200	.094	USS
1N1937	24	30	1	200	3	200	.096	USS
1N1938	30	36	.2	300	3	200	.098	USS
1N1939	36	43	.2	400	3	200	.10	USS
1N1940	43	51	.2	500	2	200	.10	USS
1N1941	51	62	.2	700	2	200	.10	USS
1N1942	62	75	.2	900	1	200	.11	USS
1N1943	75	91	.2	1200	1	200	.11	USS
1N1944	91	110	.2	1700	1	200	.12	USS
1N1945	110	130	.2	2800	1	200		USS
1N1946	130	160	.1			200		USS
1N1947	160	200	.1			200		USS
1N1948	200	240	.1			200		USS
1N1949	240	300	.1			200		USS
1N1950	300	360	.1			200		USS
1N1951	360	430	.1			200		USS
1N1952	430	510	.1			200		USS
1N1953	510	620	.1			200		USS
1N1954	3.6	4.3	5	11	10	400	.06	USS
1N1955	4.3	5.1	5	10	10	400	.05	USS
1N1956	5.1	6.2	5	8	10	400	.01	USS
1N1957	6.2	7.5	5	7	10	400	.03	USS
1N1958	7.5	9.1	5	15	10	400	.06	USS
1N1959	9.1	11.0	5	22	10	400	.065	USS
1N1960	11	13	1	30	5	400	.08	USS
1N1961	13	16	1	50	5	400	.088	USS
1N1962	16	20	1	70	5	400	.092	USS
1N1963	20	24	1	100	5	400	.094	USS
1N1964	24	30	1	200	3	400	.096	USS
1N1965	30	36	.2	300	3	400	.098	USS
1N1966	36	43	.2	400	3	400	.10	USS
1N1967	43	51	.2	500	2	400	.10	USS
1N1968	51	62	.2	700	2	400	.10	USS
1N1969	62	75	.2	900	1	400	.11	USS
1N1970	75	91	.2	1200	1	400	.11	USS
1N1971	91	110	.2	1700	1	400	.12	USS
1N1972	100	130	.2	2800	1	400		USS
1N1973	130	160	.1			400		USS
1N1974	160	200	.1			400		USS
1N1975	200	240	.1			400		USS
1N1976	240	300	.1			400		USS
1N1977	300	360	.1			400		USS
1N1978	360	430	.1			400		USS
1N1979	430	510	.1			400		USS
1N1980	510	620	.1			400		USS
1N1981	3.6	4.3	5	11	10	150	.06	USS
1N1982	4.3	5.1	5	10	10	150	.05	USS
1N1983	5.1	6.2	5	8	10	150	.01	USS
1N1984	6.2	7.5	5	7	10	150	.03	USS
1N1985	7.5	9.1	5	15	10	150	.06	USS
1N1986	9.1	11.0	5	22	10	150	.065	USS
1N1987	11	13	1	30	5	150	.08	USS
1N1988	13	16	1	50	5	150	.088	USS
1N1989	16	20	1	70	5	150	.092	USS
1N1990	20	24	1	100	5	150	.094	USS
1N1991	24	30	1	200	3	150	.096	USS
1N1992	30	36	.2	300	3	150	.098	USS
1N1993	36	43	.2	400	3	150	.10	USS
1N1994	43	51	.2	500	2	150	.10	USS
1N1995	51	62	.2	700	2	150	.10	USS
1N1996	62	75	.2	900	1	150	.11	USS
1N1997	75	91	.2	1200	1	150	.11	USS
1N1998	91	110	.2	1700	1	150	.12	USS
1N1999	110	130	.2	2800	1	150		USS
1N2000	130	160	.1			150		USS
1N2001	160	200	.1			150		USS
1N2002	200	240	.1			150		USS
1N2003	240	300	.1			150		USS
1N2004	300	360	.1			150		USS
1N2005	360	430	.1			150		USS
1N2006	430	510	.1			150		USS
1N2007	510	620	.1			150		USS
10M10Z	8.0	12.0	250	3.0	250	10W	.060	MOT
10M11Z	8.8	13.2	230	3.0	230	10W	.060	MOT
10M12Z	9.6	14.4	210	3.0	210	10W	.060	MOT
10M13Z	10.4	15.6	190	3.0	190	10W	.070	MOT
10M14Z	11.2	16.8	180	3.0	180	10W	.070	MOT
10M15Z	12.0	18.0	170	3.0	170	10W	.070	MOT
10M16Z	12.8	19.2	155	4.0	155	10W	.070	MOT
10M17Z	13.6	20.6	145	4.0	145	10W	.070	MOT
10M18Z	14.4	21.6	140	4.0	140	10W	.070	MOT
10M19Z	15.2	22.8	130	4.0	130	10W	.070	MOT
10M20Z	16.0	24.0	125	4.0	125	10W	.080	MOT
10M22Z	17.6	26.4	115	5.0	115	10W	.080	MOT
10M24Z	19.2	28.8	105	5.0	105	10W	.080	MOT
10M25Z	20.0	30.0	100	6.0	100	10W	.080	MOT

TYPE NO.	Zener or Avalanche Voltage Range MIN. Eb1 (volts)	MAX. Eb2 (volts)	@ Iz (ma)	Dynamic Impedance Z @ Iz (ohms)	(ma)	MAX. DISS. (mw)	TEMP. CO-EF-FICIENT %/°C	MFR. (See code at start of chart)
10M27Z	21.6	32.4	95	7.0	95	10W	.080	MOT
10M30Z	24.0	36.0	85	8.0	85	10W	.080	MOT
10M33Z	26.4	39.6	75	9.0	75	10W	.080	MOT
10M36Z	28.8	43.2	70	10	70	10W	.090	MOT
10M39Z	31.2	46.8	65	11	65	10W	.090	MOT
10M43Z	34.4	51.6	60	12	60	10W	.090	MOT
10M45Z	36.0	54.0	55	13	55	10W	.090	MOT
10M47Z	37.6	56.4	55	14	55	10W	.090	MOT
10M50Z	40.0	60.0	50	15	50	10W	.10	MOT
10M52Z	41.6	62.4	50	15	50	10W	.10	MOT
10M56Z	44.8	67.2	45	16	45	10W	.10	MOT
10M62Z	49.6	74.4	40	17	40	10W	.10	MOT
10M68Z	54.4	81.6	37	18	37	10W	.10	MOT
10M75Z	60.0	90.0	33	22	33	10W	.11	MOT
10M82Z	65.6	98.4	30	25	30	10W	.11	MOT
10M91Z	72.8	109.2	28	35	28	10W	.12	MOT
10M100Z	80	120	25	40	25	10W	.12	MOT
10M105Z	84	126	25	45	25	10W	.12	MOT
10M110Z	88	132	23	55	23	10W	.12	MOT
10M120Z	96	144	20	75	20	10W	.13	MOT
10M130Z	104	156	19	100	19	10W	.13	MOT
10M140Z	112	168	18	125	18	10W	.13	MOT
10M150Z	120	180	17	175	17	10W	.14	MOT
10M175Z	140	210	14	250	14	10W	.14	MOT
10M200Z	160	240	12	300	12	10W	.14	MOT
50M10Z	8.0	12.0	1200	.80	1200	50W	.06	MOT
50M11Z	8.8	13.2	1100	.90	1100	50W	.06	MOT
50M12Z	9.6	14.4	1000	1.0	1000	50W	.06	MOT
50M13Z	10.4	15.6	960	1.1	960	50W	.07	MOT
50M14Z	11.2	16.8	890	1.2	890	50W	.07	MOT
50M15Z	12.0	18.0	830	1.4	830	50W	.07	MOT
50M16Z	12.8	19.2	780	1.6	780	50W	.07	MOT
50M17Z	13.6	20.6	740	1.8	740	50W	.07	MOT
50M18Z	14.4	21.6	700	2.0	700	50W	.07	MOT
50M19Z	15.2	22.8	660	2.2	660	50W	.07	MOT
50M20Z	16.0	24.0	630	2.4	630	50W	.08	MOT
50M22Z	17.6	26.4	570	2.5	570	50W	.08	MOT
50M24Z	19.2	28.8	520	2.6	520	50W	.08	MOT
50M25Z	20.0	30.0	500	2.7	500	50W	.08	MOT
50M27Z	21.6	32.4	460	2.8	460	50W	.08	MOT
50M30Z	24.0	36.0	420	3.0	420	50W	.08	MOT
50M33Z	26.4	39.6	380	3.2	380	50W	.08	MOT
50M36Z	28.8	43.2	350	3.5	350	50W	.09	MOT
50M39Z	31.2	46.8	320	4.0	320	50W	.09	MOT
50M43Z	34.4	51.6	290	4.5	290	50W	.09	MOT
50M45Z	36.0	54.0	280	4.5	280	50W	.09	MOT
50M47Z	37.6	56.4	270	5.0	270	50W	.09	MOT
50M50Z	40.0	60.0	250	5.0	250	50W	.10	MOT
50M52Z	41.6	62.4	240	5.5	240	50W	.10	MOT
50M56Z	44.8	67.2	220	6.0	220	50W	.10	MOT
50M62Z	49.6	74.4	200	7.0	200	50W	.10	MOT
50M68Z	54.4	81.0	180	8.0	180	50W	.10	MOT
50M75Z	60.0	90.0	170	9.0	170	50W	.11	MOT
50M82Z	65.6	98.4	150	11	150	50W	.11	MOT
50M91Z	72.8	109.2	140	15	140	50W	.12	MOT
50M100Z	80	120	120	20	120	50W	.12	MOT
50M105Z	84	126	120	25	120	50W	.12	MOT
50M110Z	88	132	110	30	110	50W	.12	MOT
50M120Z	96	144	100	40	100	50W	.13	MOT
50M130Z	104	156	95	50	95	50W	.13	MOT
50M140Z	112	168	90	60	90	50W	.13	MOT
50M150Z	120	180	85	75	85	50W	.14	MOT
50M175Z	140	210	70	85	70	50W	.14	MOT
50M200Z	160	240	65	100	65	50W	.14	MOT
LPZT-10	9.1	11	25	3	25	3W	.058	USS
LPZT-12	11	13	25	4	25	3W	.059	USS
LPZT-15	13	16	25	5	25	3W	.060	USS
LPZT-18	16	20	25	8	25	3W	.060	USS
LPZT-22	20	24	7.5	20	7.5	3W	.064	USS
LPZT-27	24	30	7.5	22	7.5	3W	.066	USS
LPZT-33	30	36	7.5	24	7.5	3W	.068	USS
PR504	4.28	4.73	2000	.5	1000	10W	.02	NAE
PR505	4.75	5.25	2000	.5	1000	10W	.00	NAE
PR506	5.23	5.78	1600	.7	1000	10W	.015	NAE
PR507	5.70	6.30	1600	.7	1000	10W	.03	NAE
PR508	6.18	6.83	1200	.8	1000	10W	.038	NAE
PR509	6.65	7.35	1200	.8	1000	10W	.043	NAE
PR510	7.13	7.88	1200	.8	1000	10W	.047	NAE
PR511	7.60	8.40	1000	.8	1000	10W	.05	NAE
PR512	8.08	8.93	1000	.8	1000	10W	.054	NAE
PR513	8.55	9.45	1000	.8	1000	10W	.057	NAE
PR514	9.04	9.98	1000	.8	1000	10W	.058	NAE
PR515	9.5	10.5	800	1.5	500	10W	.06	NAE
PR516	10.45	11.55	800	1.5	500	10W	.063	NAE
PR517	11.4	12.6	700	2.0	500	10W	.066	NAE
PR518	12.35	13.65	700	2.0	500	10W	.069	NAE
PR519	13.3	14.7	700	2.0	500	10W	.072	NAE
PR520	14.24	15.75	600	3.0	500	10W	.075	NAE
PR521	15.2	16.8	600	3.0	500	10W	.076	NAE

TYPE NO.	Zener or Avalanche Voltage Range MIN. E_{b1} (volts)	MAX. E_{b2} (volts)	@ I_z (ma)	Dynamic Impedance Z @ I_z (ohms)	(ma)	MAX. DISS. (mw)	TEMP. CO-EF-FICIENT %/°C	MFR. (See code at start of chart)
PR522	16.5	17.85	500	3.0	500	10W	.077	NAE
PR523	17.1	18.9	500	3.0	500	10W	.078	NAE
PR524	18.05	19.95	500	3.0	500	10W	.079	NAE
PR525	19.0	21.0	500	3.0	500	10W	.081	NAE
PR544	20.9	23.1	400	8.0	150	10W	.084	NAE
PR545	22.8	25.2	400	8.0	150	10W	.086	NAE
PR546	24.7	27.3	350	8.0	150	10W	.088	NAE
PR604	4.28	4.73	200	1	40	1W	.02	NAE
PR605	4.75	5.25	200	1	40	1W	.00	NAE
PR606	5.23	5.78	160	1.5	35	1W	.015	NAE
PR607	5.70	6.30	160	1.5	35	1W	.03	NAE
PR608	6.18	6.83	120	2	30	1W	.038	NAE
PR609	6.65	7.35	120	2	30	1W	.043	NAE
PR610	7.13	7.88	120	2	30	1W	.047	NAE
PR611	7.60	8.40	100	3	25	1W	.05	NAE
PR612	8.08	8.93	100	3	25	1W	.054	NAE
PR613	8.55	9.45	100	3	25	1W	.057	NAE
PR614	9.04	9.98	100	3	25	1W	.058	NAE
PR615	9.5	10.5	80	4.5	20	1W	.06	NAE
PR616	10.45	11.55	80	4.5	20	1W	.063	NAE
PR617	11.4	12.6	70	7.5	15	1W	.066	NAE
PR618	12.35	13.65	70	7.5	15	1W	.069	NAE
PR619	13.3	14.7	70	7.5	15	1W	.072	NAE
PR620	14.24	15.75	60	15	13	1W	.075	NAE
PR621	15.2	16.8	60	15	13	1W	.076	NAE
PR622	16.5	17.85	50	15	13	1W	.077	NAE
PR623	17.1	18.9	50	12	10	1W	.078	NAE
PR624	18.05	19.95	50	12	10	1W	.079	NAE
PR625	19.0	21.0	50	12	10	1W	.081	NAE
PR644	20.9	23.1	40	10	9	1W	.084	NAE
PR645	22.8	25.2	40	10	9	1W	.086	NAE
PR646	24.7	27.3	35	9	9	1W	.088	NAE
PR704	4.3	5.4	2000	.5	1000	10W	.00	NAE
PR705	5.2	6.4	1600	.7	1000	10W	.015	NAE
PR706	6.2	8.0	1200	.8	1000	10W	.043	NAE
PR708	7.5	10.0	1000	.8	1000	10W	.057	NAE
PR710	9.0	12.0	800	1.5	500	10W	.06	NAE
PR712	11.0	14.5	700	2	500	10W	.069	NAE
PR715	13.5	18.0	600	3	500	10W	.075	NAE
PR718	17.0	21.0	500	3	500	10W	.079	NAE
PR724	20.0	27.0	400	8	150	10W	.086	NAE
PR804	4.3	5.4	200	.1	40	1W	.00	NAE
PR805	5.2	6.4	160	1.5	35	1W	.015	NAE
PR806	6.2	8.0	120	2	30	1W	.043	NAE
PR808	7.5	10.0	100	3	25	1W	.057	NAE
PR810	9.0	12.0	80	4.5	20	1W	.06	NAE
PR812	11.0	14.5	70	7.5	15	1W	.069	NAE
PR815	13.5	18.0	60	15	13	1W	.075	NAE
PR818	17.0	21.0	50	30	10	1W	.079	NAE
PR824	20.0	27.0	40	45	9	1W	.086	NAE
PS6313	7.5	10	.20			500		PSI
PS6314	9.0	12	.20			500		PSI
PS6315	11	14.5	.20			500		PSI
PS6316	13.5	18	.20			500		PSI
PS6317	17	21	.20			500		PSI
PS6318	20	27	.20			500		PSI
PS6319	25	32	.20			500		PSI
PS6320	30	39	.20			500		PSI
PS6321	37	45	.20			500		PSI
PS6322	43	54	.20			500		PSI
PS6323	52	64	.20			500		PSI
PS6324	62	80	.20			500		PSI
PS6325	75	100	.20			500		PSI
PS6326	90	120	.20			500		PSI
PS6327	110	145	.20			500		PSI
PS6465	2.0	3.2	5.0	60	10	500		PSI
PS6466	3.0	3.9	5.0	55	10	500		PSI
PS6467	3.7	4.5	5.0	45	10	500		PSI
PS6468	4.3	5.4	5.0	35	10	500		PSI
PS6469	5.2	6.4	5.0	20	10	500		PSI
PS6470	6.2	8.0	5.0	10	10	500		PSI
PZT-10	9.1	11	25	3	25	10W	.058	USS
PZT-12	11	13	25	4	25	10W	.059	USS
PZT-15	13	16	25	5	25	10W	.060	USS
PZT-18	16	20	25	8	25	10W	.062	USS
PZT-22	20	24	7.5	20	7.5	10W	.064	USS
PZT-27	24	30	7.5	22	7.5	10W	.066	USS
PZT-33	30	36	7.5	24	7.5	10W	.068	USS
S1200	8.9	9.8	10	15	10	150	.005	USS
S1201	8.9	9.8	10	15	10	150	.002	USS
S1202	8.9	9.8	10	15	10	150	.002	USS
S1203	9.2	9.7	10	15	10	150	.001	USS
S1204	9.2	9.7	10	15	10	150	.001	USS
S1205	9.2	9.7	10	15	10	150	.0005	USS
S320G*	.222	.298	1.0	50	1.0		.077	TRA
S1010*	.222	.298	1.0	50	1.0		.077	TRA
SG22	.576	.704	1.0	45	1.0		.031	TRA
SM72	.513	.627	1.0	40	1.0		.035	TRA

* GERMANIUM

CHARACTERISTICS CHART of NEW TRANSISTORS

MANUFACTURERS (In Order of Code Letters)

- ARA— Advanced Research Associates, Inc.
- AMP— Amperex Electronic Corp.
- BEN— Bendix Aviation Corp.
- BOG— Bogue Electric Mfg. Co.
- BTHB— British Thomson-Houston Export Co., Ltd.
- CBS— CBS-Hytron
- CTP— Clevite Transistor Products, Inc.
- DEL— Delco Radio Div., General Motors Corp.
- EEVB— English Electric Valve Co., Ltd.
- ESEB— Edison Swan Electric Co., Ltd.
- FSC— Fairchild Semiconductor Corp.
- FTHF— French Thomson-Houston Semiconductor Dept.
- GECB— General Electric Co., Ltd.
- GE— General Electric Co.
- GEM— Great Eastern Mfg. Co.
- GTC— General Transistor Corp.
- HUG— Hughes Aircraft Co.
- HIVB— Hivac Ltd.
- IND— Industro Transistor Corp.
- LCTF— Labortoire Central de Telecommunications
- MIN— Minneapolis-Honeywell Regulator Co.
- MOT— Motorola, Inc.
- MUL— Mullard Ltd.
- NPC— Nucleonics Products Co.
- PHI— Philco Corp., Landsdale Tube Co.
- PYEB— Pye Industrial Electronics, Ltd.
- RAY— Raytheon Mfg. Co.
- RCA— Radio Corp. of America, Semiconductor Div.
- SIE— Siemens & Halske Aktiengesellschaft
- SONY— Sony Corp.
- SPE— Sperry Gyroscope Co.
- SPR— Sprague Electric Co.
- SYL— Sylvania Electric Products Inc.
- STCB— Standard Telephone & Cables, Ltd.
- TKAD— Suddeutsche Telefon-Apparate-, Kabel und Draht-werke
- TRA— Transitron Electronic Corp.
- TFKG— Telefunken Ltd.
- TI— Texas Instruments
- TUN— Tung-Sol Electric, Inc.
- WEC— Western Electric Co., Inc.
- WEST— Westinghouse Electric Corp.

CHARACTERISTICS CHART of NEW TRANSISTORS

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C: P_c (mw)	DERATING °C/W	V_{CB}	V_{CE}	Typical Characteristics: $f_{\alpha\beta}$ (mc)	Gain: PARAMETER and (condition)	VALUE	MFR. See code at start of charts
2N59A	2	PNPA	Ge	180	333	40	20	1.8	h_{FE}: 100ma	90	WEST
2N59B	2	PNPA	Ge	180	333	50	20	1.8	h_{FE}: 100ma	90	WEST
2N59C	2	PNPA	Ge	180	333	60	20	1.8	h_{FE}: 100ma	90	WEST
2N60A	2	PNPA	Ge	180	333	40	20	1.5	h_{FE}: 100ma	70	WEST
2N60B	2	PNPA	Ge	180	333	50	20	1.5	h_{FE}: 100ma	70	WEST
2N60C	2	PNPA	Ge	180	333	60	20	1.5	h_{FE}: 100ma	70	WEST
2N61A	2	PNPA	Ge	180	333	40	20	1.0	h_{FE}: 100ma	45	WEST
2N61B	2	PNPA	Ge	180	333	50	20	1.0	h_{FE}: 100ma	45	WEST
2N61C	2	PNPA	Ge	180	333	60	20	1.0	h_{FE}: 100ma	45	WEST
2N297A	3	PNPA	Ge	35W	2.0	60	50	f_{ae}-.02	h_{FE}: I_c- .5A	70	DEL
2N311	5	PNPA	Ge	150	500	15	15		h_{FE}: I_c- 10ma	50	GTC
2N312	5	NPNA	Ge	150	500	15	15		h_{FE}: I_c- 10ma	50	GTC
2N331	1	PNPA	Ge	200	300	30	30	1.16	h_{FE}: I_c- 50ma	60	RCA
2N350A	3	PNPA	Ge	45W	1.0	40	30	.30	h_{FE}: .70A	30	MOT
2N351A	3	PNPA	Ge	45W	1.0	40	30	.40	h_{FE}: .70A	45	MOT
2N376A	3	PNPA	Ge	45W	1.0	40	30	.50	h_{FE}: .70A	60	MOT
2N438A	5	NPNA	Ge	150	.40	30	25	4.0	h_{FE}: I_c- 50ma	25	CBS
2N439A	5	NPNA	Ge	150	.40	30	20	7.5	h_{FE}: I_c- 50ma	45	CBS
2N440A	5	NPNA	Ge	150	.40	30	15	12	h_{FE}: I_c- 50ma	70	CBS
2N475A	2	NPN	Si	200	910	45	45	10	h_{fe}: I_c- 1ma	30	TRA
2N476A	2	NPN	Si	200	910	15	15	17	h_{fe}: I_c- 1ma	45	TRA
2N477A	2	NPN	Si	200	910	30	30	17	h_{fe}: I_c- 1ma	45	TRA

NOTATIONS

Under Use

1—Low power a-f equal to or less than 50 mw
2—Medium power a-f > 50 mw and equal to or less than 500 mw
3—Power > 500 mw
4—r-f/i-f
5—Switching & Computer

Under Type and Type No.

A—Alloyed
D—Diffused or Drift
G—Grown
H—Hook Collector
M—Microalloy
O—Other
P—Previously released with new specs
S—Surface Barrier
UNI—Unijunction Transistor
Y—Symmetrical

Under $f_{\alpha b}$

* Maximum Frequency
# Figure of Merit

Other

6—Phototransistors
7—@ 70° C
8—I_{CBO} (V_{CB} = −20) = −25 μA
9—Rise time —2 μsec
10—Rise time —3.5 μsec
11—Rise time —6.5 μsec
12—Frequency for $f_{\alpha b}$ = 1

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For further information circle No. 14 on Reader Service Card

MEDIUM FREQUENCY, MEDIUM POWER ALLOY JUNCTION TRANSISTORS (250 mw) (in TO-9 package)

2N597......for use in 200-300 kc computers, $f\alpha_b$ over 3 mc
2N598......for use in 300-400 kc computers, $f\alpha_b$ over 5 mc
2N599......for use in switching circuits faster than 400 kc, $f\alpha_b$ over 12 mc

MICRO-MINIATURE TRANSISTOR

2N536......high gain switching transistor, 20v maximum V_{CE}, DC beta typically 150

HIGH FREQUENCY, HIGH GAIN (MICRO ALLOY) TRANSISTOR (MAT)

2N393......combines high frequency response with high gain for general purpose, high frequency applications and switching circuits, typical f_{max} 60 mc

HIGH FREQUENCY SILICON TRANSISTOR (SAT)

2N496......high speed silicon switch for speeds up to 5 mc characterized by extremely low saturation resistance.

HIGH FREQUENCY SURFACE BARRIER TRANSISTOR (SBT)

2N240......switching transistor, typical f=60 mc

MICRO ALLOY DIFFUSED-BASE TRANSISTOR (MADT)

2N501......extremely high speed switch; typical rise time 12 mμ sec, fall time 4 mμ sec

BILATERAL ALLOY JUNCTION TRANSISTOR

2N462......high gain (h_{FE} = 45 in both directions), high voltage (40v) unit for applications where current reversal is desired

POWER TRANSISTORS

2N353......40 volt, 30 watt power transistor
2N386......60 volt, 37.5 watt power transistor
2N387......80 volt, 37.5 watt power transistor
2N589......100 volt, 37.5 watt power transistor

PHILCO'S NEWEST FAMILY OF MEDIUM- AND HIGH-POWER SWITCHING TRANSISTORS

2N670......300 mw, 2 amp pulse amplifier, in TO-9 type package
2N671......40 volt, 1 watt pulse amplifier in case with mounting stud and JETEC E3-51 base
2N672......40 volt, 0.75 microsecond high frequency switching transistor
2N673......40 volt, 1 watt, stud mounted switching transistor
2N600......stud mounted ¾ watt high speed power switch ($f\alpha_c$ and 5 MC)
2N601......stud mounted ¾ watt high speed power switch ($f\alpha_c$ and 12 MC)

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PHILCO CORPORATION

LANSDALE TUBE COMPANY DIVISION

LANSDALE, PENNSYLVANIA

TRANSISTOR CENTER U.S.A.

CHARACTERISTICS CHART of NEW TRANSISTORS

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C: P_c (mw)	DERATING °C/W	V_{CB}	V_{CE}	Typical Characteristics: $f_{\alpha\beta}$ (mc)	Gain: PARAMETER and (condition)	Gain: VALUE	MFR. (See code at start of charts)
2N478A	2	NPN	Si	200	910	15	15	11	h_{fe}: I_c - 1ma	60	TRA
2N480A	2	NPN	Si	200	910	45	45	11			TRA
2N541A	2	NPN	Si	200	910	15	15	15	h_{fe}: I_c - 1ma	130	TRA
2N542A	2	NPN	Si	200	910	30	30	15	h_{fe}: I_c - 1ma	130	TRA
2N543A	2	NPN	Si	200	910	45	45	15	h_{fe}: I_c - 1ma	130	TRA
2N600	3,5	PNPA	Ge	750		30	20	7.5	h_{FE}: 1V,100ma	70	PHIL
2N601	3,5	PNPA	Ge	750		30	20	5.0	h_{FE}: 1V,100ma	105	PHIL
2N647	2	NPNA	Ge	100		25	25		h_{FE}: I_c - 50ma	70	RCA
2N673	3,5	PNPA	Ge	1000		25	25		t_r - .5usec. max.		PHIL
2N695	5	PNPD	Ge	50	1000	15	12				MOT
2N696	3,4,5	NPND	Si	2000	75	40	40	120*	h_{FE}: I_c-150ma	25	FSC
2N697	3,4,5	NPND	Si	2000	75	40	40	120*	h_{FE}: I_c-150ma	50	FSC
2N700	4	PNPD	Ge	50	1000	30	30	600	PG: 200Mc	12db	MOT
2N1013	3	PNPA	Ge	5000	14	60			h_{FE}: I_c - 88ma	22	MIN
2N1031	3,5	PNP	Ge		1.5		30		h_{FE}: I_c - 15A	60	BEN
2N1031A	3,5	PNP	Ge		1.5		40		h_{FE}: I_c - 15A	60	BEN
2N1031B	3,5	PNP	Ge		1.5		70		h_{FE}: I_c - 15A	60	BEN
2N1031C	3,5	PNP	Ge		1.5		80		h_{FE}: I_c - 15A	60	BEN
2N1032	3,5	PNP	Ge		1.5		30		h_{FE}: I_c - 15A	100	BEN
2N1032A	3,5	PNP	Ge		1.5		40		h_{FE}: I_c - 15A	100	BEN
2N1032B	3,5	PNP	Ge		1.5		70		h_{FE}: I_c - 15A	100	BEN
2N1032C	3,5	PNP	Ge		1.5		80		h_{FE}: I_c - 15A	100	BEN
2N1034	2	PNP	Si	380	350	50	40	.20	h_{fe}: I_e - 3ma	15	RAY
2N1035	2	PNP	Si	380	350	50	35	30	h_{fe}: I_e - 3ma	30	RAY
2N1036	2	PNP	Si	380	350	50	30	.40	h_{fe}: I_e - 3ma	60	RAY
2N1037	2	PNP	Si	380	350	50	35	.25	h_{fe}: I_e - 3ma	25	RAY
2N1058	1	NPN	Ge	50	1000		20	6.0	h_{fe}: 1ma	16.5	SYL
2N1059	2	NPN	Ge	180	277	40	15	f_{ae}-.01	h_{FE}: 35ma	75	SYL
2N1073	3,5	PNPDA	Ge	35W	2.0	40	40	1.5	h_{FE}: I_c - 5A	40	BEN
2N1073A	3,5	PNPDA	Ge	35W	2.0	80	80	1.5	h_{FE}: I_c - 5A	40	BEN
2N1073B	3,5	PNPDA	Ge	35W	2.0	120	120	1.5	h_{FE}: I_c - 5A	40	BEN
2N1074	2	NPN	Si	380	350	50	50	.20	h_{fe}: I_e - 3ma	15	RAY
2N1075	2	NPN	Si	380	350	50	40	.35	h_{fe}: I_e - 3ma	30	RAY
2N1076	2	NPN	Si	380	350	50	30	50	h_{fe}: I_e - 3ma	60	RAY
2N1077	2	NPN	Si	380	350	50	30	.30	h_{fe}: I_e - 3ma	25	RAY
2N1099	3	PNPA	Ge	72W	1.0	80	70	f_{ae}-.01	h_{FE}: I_c - 5A	50	DEL
2N1100	3	PNPA	Ge	72W	1.0	100	80	f_{ae}-.01	h_{FE}: I_c - 5A	39	DEL
2T69	2	NPNA	Ge	100	500	25			PP class B	100mw	SONY
2T78	4	NPNG	Ge	50	1000	15		30	10Mc	13	SONY
2T201	4	PNPG	Ge	30	1300	15		50	10Mc	20	SONY
2T204	4	PNPG	Ge	30	1300	15		50	10Mc	16	SONY
2T205	4	PNPG	Ge	30	1300	15		60	10Mc	24	SONY
44T1	2	PNP	Ge	400	150	45		1.2	h_{fe}: I_c - 1ma	54	FTHF
CTP1511	3,5	PNP	Ge	65W	1.0	100	75		h_{FE}: I_c - 5A	90	CTP
CTP1512	3,5	PNP	Ge	65W	1.0	80	60		h_{FE}: I_c - 5A	90	CTP

NOTATIONS

Under Use

1—Low power a-f equal to or less than 50 mw
2—Medium power a-f > 50 mw and equal to or less than 500 mw
3—Power > 500 mw
4—r-f/i-f
5—Switching & Computer

Under Type and Type No.

A—Alloyed
D—Diffused or Drift
G—Grown
H—Hook Collector
M—Microalloy
O—Other
P—Previously released with new specs
S—Surface Barrier
UNI—Unijunction Transistor
Y—Symmetrical

Under f_{ab}

* Maximum Frequency
\# Figure of Merit

Other

6—Phototransistors
7—@ 70° C
8—I_{CBO} (V_{CB} = −20) = −25 μA
9—Rise time —2 μsec
10—Rise time —3.5 μsec
11—Rise time —6.5 μsec
12—Frequency for f_{ab} — 1

Specially engineered Transistors to meet the specific needs of Control Circuitry . . . from Philco Transistor Center, U. S. A.

System designers now have, at their fingertips, a full range of outstandingly reliable transistors to meet the specific requirements of counters, metering devices, amplifiers, logic elements, relay drivers, pulse modulators, pulse line drivers and many other instrumentation applications.

2N226—250 mw high gain, low frequency PNP germanium junction transistor for medium power relay driver and signal output applications.

2N240—general purpose, PNP germanium surface barrier high speed switching transistor for use in counters and logic circuits.

2N386—60v. germanium power transistor for servo amplifiers, high power-high voltage audio circuits, servo amplifier output stages, dc.-to-dc. converters and high power relay drivers.

2N393—high gain, high speed germanium micro alloy transistor, especially well suited to wide fan-in and fan-out logic systems.

2N496—very low saturation resistance, high switching speed PNP Silicon surface alloy transistor for high temperature counters and logic elements.

2N501—high gain, super high frequency germanium micro alloy switching transistor for use in extra high frequency counters, logic circuits and wide-band video amplifiers.

2N502—very high frequency small signal amplifier micro alloy transistor for general purpose amplification at frequencies up to 400 m.c.

2N535—micro-miniature high gain, general purpose audio frequency germanium PNP junction transistor for use in metering decoders, signal amplifiers and telemetering applications where outstanding reliability is required in minimum space.

2N598—medium frequency, medium power, high current PNP alloy junction transistor for counters and logic circuits.

2N600—studded version of 2N598 for applications requiring higher power dissipation.

2N670—very high peak current, high voltage, low frequency PNP germanium alloy junction transistor in JETEC-type package. The 2N670 is specifically engineered for pulse modulators and pulse line drivers.

2N671—specially studded version of 2N670 for applications where high average dissipation is encountered.

Make Philco your prime source for all transistor information and prices. Write Dept. SP-159

Circle No. 15 on Reader Service Card

PHILCO CORPORATION
LANSDALE TUBE COMPANY DIVISION
LANSDALE, PENNSYLVANIA

TRANSISTOR CENTER U.S.A.

CHARACTERISTICS CHART of NEW TRANSISTORS

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C: P_c (mw)	DERATING °C/W	V_{CB}	V_{CE}	Typical Characteristics: $f_{\alpha b}$ (mc)	Gain: PARAMETER and (condition)	VALUE	MFR. See code at start of charts
CTP1513	3,5	PNP	Ge	65W	1.0	60	40		h_{FE}: I_c- 5A	90	CTP
CTP1514	3,5	PNP	Ge	65W	1.0	40	30		h_{FE}: I_c- 5A	90	CTP
GET103	2	PNPA	Ge	150	200	30	20	1.0	h_{fe}: I_c-150ma	90	GECB
GET104	2	PNPA	Ge	150	200	30	30	1.0	h_{fe}: I_c-150ma	40	GECB
GET105	3	PNPA	Ge	600	50	40	30	1.0	h_{fe}: I_c-150ma	40	GECB
GET106	6	PNPA	Ge	150	200	15	15	1.0	h_{fe}: I_c-150ma	90	GECB
GET110	5	PNPA	Ge	600	50	40	30	1.0	h_{fe}: I_c-150ma	40	GECB
GET114	2	PNPA	Ge	150	200	15	15	1.0	h_{fe}: I_c-150ma	90	GECB
GET115	2	PNPA	Ge	600	50	15	15	.95	h_{fe}: I_c- 50ma	70	GECB
GET116	2	PNPA	Ge	600	50	30	20	.90	h_{fe}: I_c- 50ma	60	GECB
GET120	5	PNPA	Ge	600	50	30	20	1.1	h_{fe}: I_c- 50ma	60	GECB
GET871	5	PNPA	Ge	60	750	15	12	5.0	h_{fe}: I_c- 25ma	30	GECB
GET872	5	PNPA	Ge	60	750	12	10	10	h_{fe}: I_c- 25ma	60	GECB
GET873	4	PNPA	Ge	60	750	12	10	5.0	h_{fe}: I_c- 1ma	35	GECB
GET874	4	PNPA	Ge	60	750	13	10	10	h_{fe}: I_c- 1ma	40	GECB
GT1200	5	NPNA	Ge	120	500	90	90		h_{FE}: I_c- 5ma	20	GTC
GT1201	5	NPNA	Ge	120	500	75	75	3.0	h_{FE}: I_B- 1ma	30	GTC
GT1202	5	NPNA	Ge	120	500	45	45	5.0	h_{FE}: I_B- 1ma	30	GTC
H12	3	PNPA	Ge	100W	.70	60		3Kc	h_{FE}: I_c- 10A	50	MIN
H12A	3	PNPA	Ge	100W	.70	80		3Kc	h_{FE}: I_c- 10A	50	MIN
ST1026	2	NPN	Si	200	910	6.0	6.0	5.0	h_{FE}: I_c- 5ma	25	TRA
ST1050	2	NPN	Si	200	910	6.0	6.0	5.0	h_{FE}: I_c- 5ma	20	TRA
ST4044	3	NPN	Si	5000		60	60	4.0	h_{FE}: I_c-500ma	40	TRA
ST4045	3	NPN	Si	5000		60	60	4.0	h_{FE}: I_c-500ma	40	TRA
THP61	2	NPN	Si	150		15		2.0			FTHF
THP62	2	NPN	Si	1150		15		2.0			FTHF
TK20B	2	PNPA	Ge	140	250	30		6.3	h_{fe}: I_e- 1ma	43	STCB
TK21B	2	PNPA	Ge	140	250	30		2.0	h_{fe}: I_e- 20ma	23	STCB
TK23A	2	PNPA	Ge	180	250	50		1.0	h_{fe}: I_e- 1ma	50	STCB
TK24B	2	PNPA	Ge	140	250	30		2.5	h_{fe}: I_e- 40ma	32	STCB
TK25B	2	PNPA	Ge	140	250	20		10	h_{fe}: I_e- 1ma	63	STCB
TK26B	2	PNPA	Ge	140	250	30		2.0	h_{fe}: I_e- 20ma	23	STCB
TK27B	2	PNPA	Ge	140	250	30		2.5	h_{fe}: I_e- 40ma	32	STCB
TK40A	2	PNPA	Ge	180	250	40		1.5	h_{fe}: I_e- 1ma	90	STCB
TS17	2	PNPA	Ge	130	275	36		.60	h_{fe}: I_e- 10ma	70	STCB
V15/20IP	3	PNP	Ge		25	15		.25	h_{FE}: I_c- 20ma	40	PYE
V30/20IP	3	PNP	Ge		25	30		.25	h_{FE}: I_c- 20ma	40	PYE
WX1015	3	NPN	Si	100W	.70	30-300	30-300	.30	h_{FE}: I_c- 2A	10	WEST
WX1016	3	NPN	Si	100W	.70	30-300	30-300	.30	h_{fe}: I_c- 5A	10	WEST
XB104	1	PNPA	Ge	90	.33	20	16		h_{fe}: I_c- 1ma	30	ESEB

NOTATIONS

Under Use

1—Low power a-f equal to or less than 50 mw
2—Medium power a-f > 50 mw and equal to or less than 500 mw
3—Power > 500 mw
4—r-f/i-f
5—Switching & Computer

Under Type and Type No.

A—Alloyed
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M—Microalloy
O—Other
P—Previously released with new specs
S—Surface Barrier
UNI—Unijunction Transistor
Y—Symmetrical

Under $f_{\alpha b}$

* Maximum Frequency
# Figure of Merit

Other

6—Phototransistors
7—@ 70° C
8—I_{CBO} (V_{CB}=—20) =—25 μA
9—Rise time —2 μsec
10—Rise time —3.5 μsec
11—Rise time —6.5 μsec
12—Frequency for $f_{\alpha b}$=1

The following manufacturers have announced that they have begun supplying the indicated previously registered transistors.

CBS-Hytron: 2N301, 2N301A, 2N356, 2N357, 2N358, 2N377, 2N385, 2N388
General Electric: 2N334, 2N336, 2N337, 2N338, 2N404
Sylvania: 2N404, 2N405, 2N407
Transitron: 2N404, 2N413A, 2N424, 2N425, 2N426, 2N427, 2N428

First from **PHILCO**

MADT* TRANSISTORS CONTROLLED IN DESIGN AND MANUFACTURE...

to meet your exact circuit requirements ...NOT SELECTED!

Actual photo of Philco's out-in-front automatic precision etching production equipment.

*Trademark Philco Corporation for Micro Alloy Diffused-base Transistor.

New VHF-UHF Transistors available in unlimited quantities – at realistic prices!

NOW, TRANSISTOR CENTER, U. S. A., offers a new family of MADT (field flow) transistors in unlimited quantities. Here are precision transistors which greatly expand the design potentials of high-gain, high frequency amplifiers; high speed computers; high-gain, wideband video amplifiers; and other critical high frequency circuitry.

Due to Philco's exclusive electrochemical manufacturing process, MADT's are *controlled* not *selected*. The electrodes are precisely placed in the graded field to produce the exact characteristics you require. MADT's are available immediately in unlimited quantities. Quantities 1 to 99 available "off-the-shelf" from your local franchised Philco Industrial Transistor Distributor.

MADT FAMILY APPLICATIONS DATA

TYPE*	f_{max}	Power Gain	Oscillator Efficiency	Class of Use
2N499	320 mc	10 db at 100 mc		amplifier to 125 mc
2N500			45% at 200 mc	Oscillator to 350 mc
2N501	Ultra high-speed switch typical t_r = 9 mμsec; (18 max.); t_s = 9 mμsec; (12 max.); t_f = 7 mμsec; (10 max.) in circuit with current gain of 10 and voltage turnoff.			
2N502†	800 mc	11 db at 200 mc		amplifier to 250 mc
2N503†	420 mc	12.5 db at 100 mc		amplifier to 175 mc
2N504	50 mc (min.)	46 db at 455		high gain IF amplifier
2N588	250 mc	14 db at 50 mc		Oscillator and amplifier to 80 mc

*Available in voltage ratings up to 35 V and dissipation ratings to 50 mw at 45°C.
†In JETEC TO-9 Case (Widely known as JETEC 30 Case).

Make Philco your prime source of information for high frequency transistor applications.
Write to Lansdale Tube Company, Division of Philco Corporation, Lansdale, Pa., Dept. SP 159

PHILCO CORPORATION

LANSDALE TUBE COMPANY DIVISION

LANSDALE, PENNSYLVANIA

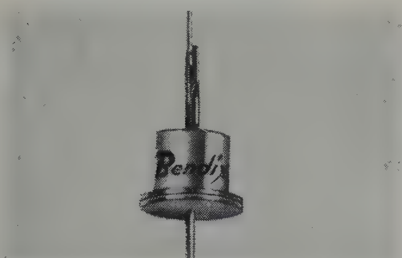
For further information circle No. 16 on Reader Service Card

New Products

Diffused Junction Silicon Rectifier

Bendix announces a series of new silicon rectifiers having peak inverse voltage ratings ranging from 50 to 600 volts and delivering 750 mAdc of rectified current at 50°C and 250 at 150°C. The EIA designations for this series are 1N536, 1N537, 1N538, 1N539, 1N540 and 1N547. Besides application to power rectification, these units are useful in magnetic amplifier and DC blocking circuits.

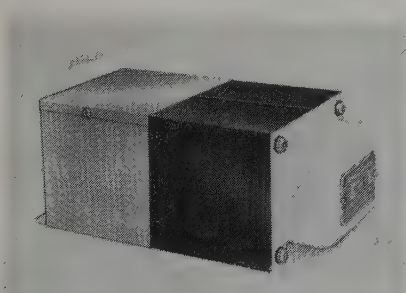
Circle 150 on Reader Service Card



Electric Voltage Stabilizers

Constant voltage stabilizers announced by Acme Electric Corp. incorporate automatic overload or short circuit protection when load current is increased in excess of normal operating load. Standard units will operate within ±1% of stabilized nominal output voltage even with a fluctuating input voltage ranging 30% of nominal.

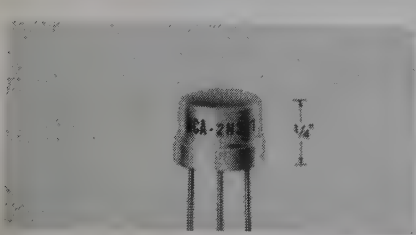
Circle 153 on Reader Service Card



New Junction Transistor

The 2N331 is a germanium alloy-junction transistor of the p-n-p type especially designed for use as a low-power audio-frequency amplifier in critical industrial and military applications. It features low collector and emitter cutoff currents, low base resistance, typical power gain of 44 db, typical noise factor of 9 db, has flexible leads and is hermetically sealed.

Circle 162 on Reader Service Card



Smaller Axial-Lead Resistors

Tiny 2 and 2½ watt vitreous-enamel power wirewound resistors have been introduced by the Sprague Electric Company as part of a new series of its axial-lead Blue Jacket Resistors for industrial applications. The 2 watt resistor is only

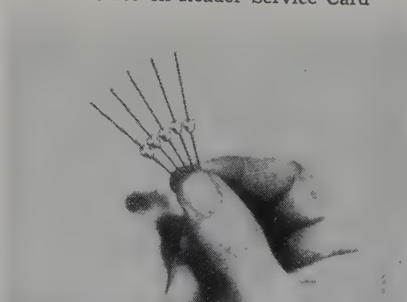
3/16" by 3/8" long while the 2½ watt resistor is only 3/16" by 17/32" long. The series includes a 3 watt resistor, a new and smaller 5 watt resistor, and new 7 and 11 watt ratings in the sizes of the previous 5 and 10 watt units. Write for bulletin 7410 and 7400A.

Circle 158 on Reader Service Card

Miniature Silicon Rectifier

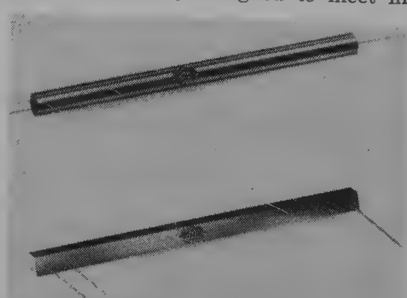
The recently developed line of Tarzian "F" series silicon rectifiers is rated at 750 milliamperes dc with voltage ratings of 200, 400 and 600 volts. These rectifiers are encapsulated into a volume less than .004 cubic inch.

Circle 163 on Reader Service Card



New Delay Lines

JFD Electronics Corporation Delay Lines, both lumped and distributed constant types, are available for printed circuit assembly or for conventional mounting. The new units can also be modified or especially designed to meet in-



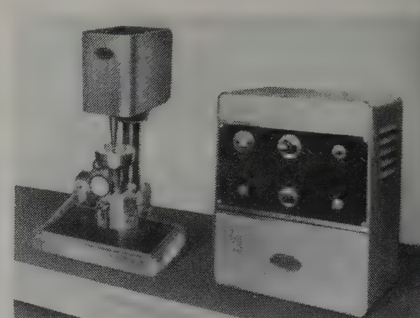
dividual requirements, are recommended for applications calling for short delay intervals, and offer a high ratio of delay to pulse rise time, in minimum space. Other characteristics are precise pulse fidelity; operating temperature range of −55°C to +125°C; excellent temperature stability; rugged encapsulated construction resists environmental mositure, humidity, shock and vibration; linear phase shift; 0.1 inch grid spacing for printed board types; attenuation of approximately 1 db per μ sec. Write for bulletin 213.

Circle 198 on Reader Service Card

Ultrasonic Impact Grinder

An ultrasonic impact grinder using a magnetostrictive transducer to permit a 100% duty cycle is announced by the Industrial Equipment Department of Raytheon Manufacturing Company. The unit is used for cutting, slicing, drilling, grinding and trepanning regular or irregular shapes. Among the substances that can be worked are semiconductors, ceramics, ferrites, carbides, metals, jewels and other hard or brittle materials.

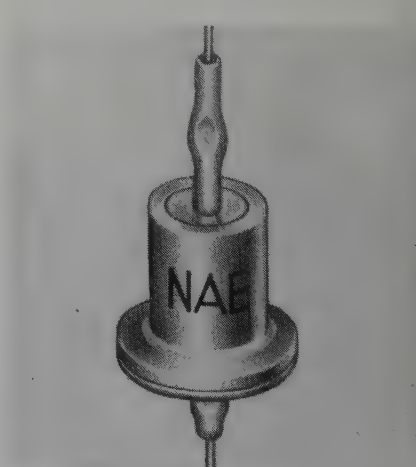
Circle 161 on Reader Service Card



Silicon Power Rectifiers

North American Electronics, Inc, announces the availability of the NL line of general purpose axial lead silicon power rectifiers designed for efficient operation in ambient temperatures up to 100°C. All types have an average output current rating of 500 milliamperes at 100°C with PIV's from 50 to 500 volts.

Circle 168 on Reader Service Card



Diffused Silicon Rectifiers

Texas Instruments Incorporated announces a new series of diffused silicon rectifiers 1N2069, 1N2070, 1N2071 featuring an average forward current of 750 milliamperes. They are packaged in a nylon-cased epoxy capsule providing an insulated case with minimum lead-to-case

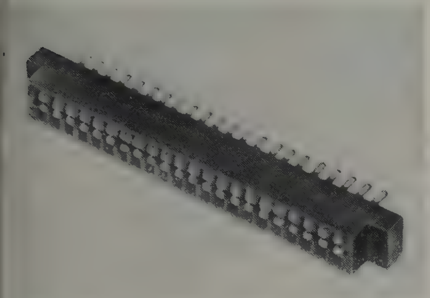
insulation resistance of 10^{10} ohms at 600 volts and have peak inverse voltages of 200, 400 and 600 volts, respectively. They also highlight a six ampere recurrent peak current and a surge (turn-on) current over 32 amperes for one millisecond.

Circle 160 on Reader Service Card

Printed Circuit Connectors

Available in double or single rows up to 22 contacts in any length and combination from Garde Mfg. Contacts are 0.200" on centers for automation applications. They are for 1/16" printed circuit boards which have been automatically assembled on the decimal system. Positive contact is assured by full surface insertion and low surface force. Designed to assure positive contact regardless of normal tolerance variations and thickness of boards.

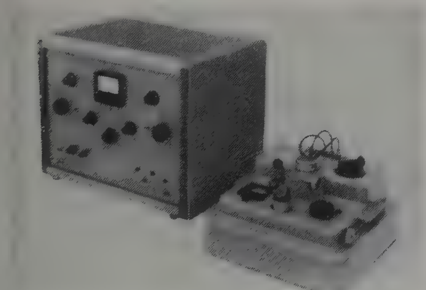
Circle 187 on Reader Service Card



Potentiometer Linearity Tester

Model LT-2 has just been introduced by Boller and Chivens, Inc. Designed for use as a production inspection gage features include capability of continuous and automatic measurement after initial adjustment and trim; in production testing, the unit will stop automatically when non-linearity exceeds a pre-selected tolerance; and percentage deviation from linearity is indicated directly on a panel meter.

Circle 152 on Reader Service Card



Infrared Detectors

Philco announces three new types of long wavelength infrared detectors made from single crystals of semiconducting materials. The detecting elements are single-crystals of indium antimonide and n- and p-type, gold-doped germanium which provide high sensitivities out to the far infrared. Operation at liquid nitrogen temperatures is required for all three detectors and can be obtained by using miniature cryostats.

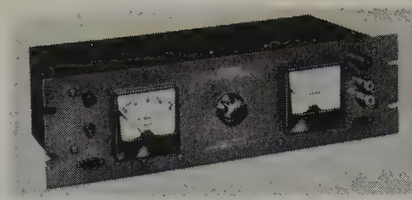
Circle 159 on Reader Service Card

Solid State Electronic Counters

A new line of AC and battery powered totalizing and AC predetermined electronic counters for laboratory or production control service has been announced by the Redford Corporation. Extremely

compact and lightweight. Has no moving parts. Several accessories are available: magnetic pick-ups, infra-red beam pick-ups, stylus pick-ups and pulse shaping pre-amplifiers which obtain operating power from the counter itself . . . no special power supplies are needed.

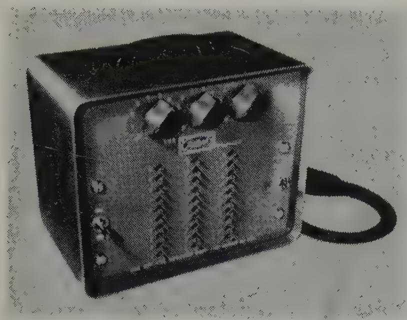
Circle 156 on Reader Service Card



Panel Mounted Power Supplies

Nutron Manufacturing announces MVAU Series of regulated variable AC power supplies designed without moving parts, vacuum tubes and internal adjustments. The new units are useful in testing diodes, rectifiers, transformers, motors, chokes; for instrument calibration; regulated adjustable line source; over and under voltage testing; and as a constant voltage source for critical photometry applications. Models are available with VA ratings of 60 to 500 and from 3 to 20 amps.

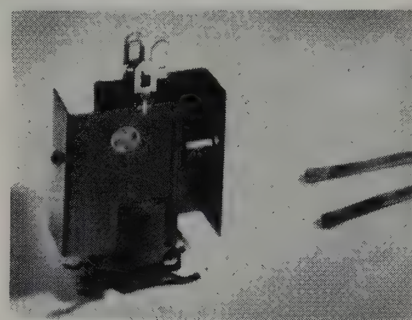
Circle 200 on Reader Service Card



Replacement Rectifiers

General Electric has revised its line of snap-in germanium rectifiers for the direct replacement of selenium rectifiers in television sets. One 400-milliampere halfwave rectifier 1N1008 and one 400-milliampere doubler rectifier 1N1016 replace the entire line of five replacement types. Both deliver 400-milliampere D-C output current into a load at 70° C. or 158° F. and are rated at a peak inverse voltage of 380 volts and an RMS input voltage of 130 volts.

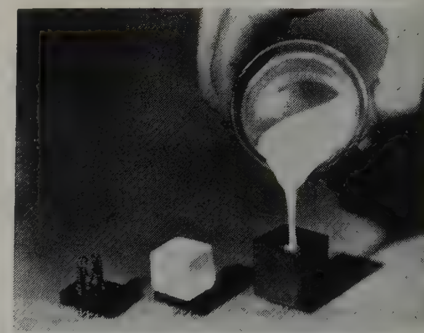
Circle 165 on Reader Service Card



Casting Resin

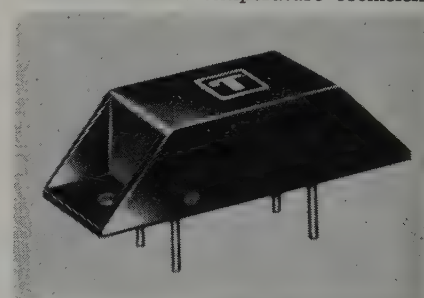
Stycast TPM-4 produced by Emerson & Cuming, is curable in the range of 400°F. to 500°F. It is a rigid, thermosetting plastic and hexagonal steel bars have been embedded and shocked from +300°F. to —70°F. without failure. Shrinkage during cure is very low and thermal stability is continuous at 500°F. The curing schedule is long and slow but simple to accomplish even when large sharp-edged objects are embedded. Write for Technical Bulletin 7-2-1A.

Circle 197 on Reader Service Card



Zener Diode-Transistor Combo

A new device combines in a single package a voltage reference (temperature compensated zener diode) and an amplifying transistor. "Ref-Amp" provides a combined temperature coefficient



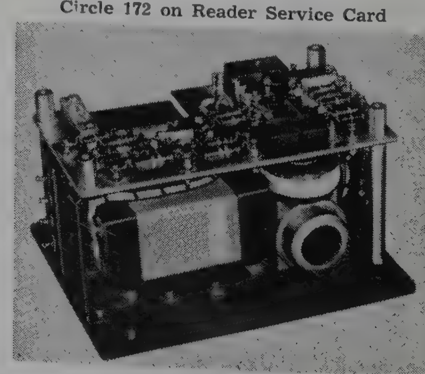
as low as .002% per degree C over a temperature range of —55°C to + 100°C. Regulator circuits requiring 10 or more components, may now be designed with one transistor, one Ref-Amp, and four resistors. Write for bulletin TE-1352.

Circle 167 on Reader Service Card

30 VA To 300 VA Static Inverters

These units, designed by Magnetic Amplifiers for aircraft and missile applications, utilize transistor and magnetic amplifiers to convert 28V DC to 115V 400 cps 1 phase or 3 phase. Voltage regulation ±3% at zero to full load with input variations of 10%. Frequency output ±2%. The line is extensive and covers other input voltages and output frequencies. Ambient temperature range —55°C to 71°C.

Circle 172 on Reader Service Card



PERSONNEL NOTES

Election of Raymond F. Kelley as Chairman of the Board and President of Dynamics Corporation of America, succeeding the late David T. Bonner, was announced recently. Vice President and Director of DCA since 1952, Mr. Kelley was also elected Chairman of the Board and President of Reeves Instrument Corporation and President of Waring Products Corporation, both subsidiaries of Dynamics Corporation of America.

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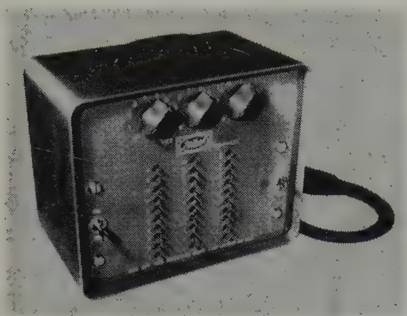
(*Continued on page 60*)

compact and lightweight. Has no moving parts. Several accessories are available: magnetic pick-ups, infra-red beam pick-ups, stylus pick-ups and pulse shaping pre-amplifiers which obtain operating power from the counter itself . . . no special power supplies are needed.

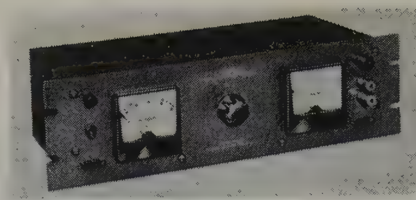
Circle 156 on Reader Service Card



Panel Mounted Power Supplies

Nutron Manufacturing announces MVAU Series of regulated variable AC power supplies designed without moving parts, vacuum tubes and internal adjustments. The new units are useful in testing diodes, rectifiers, transformers, motors, chokes; for instrument calibration; regulated adjustable line source; over and under voltage testing; and as a constant voltage source for critical photometry applications. Models are available with VA ratings of 60 to 500 and from 3 to 20 amps.

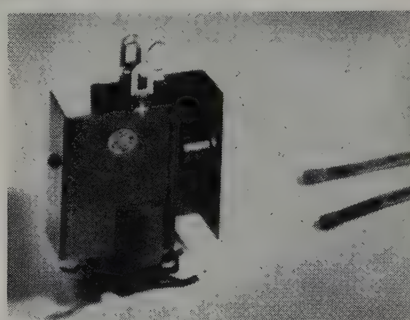
Circle 200 on Reader Service Card



Replacement Rectifiers

General Electric has revised its line of snap-in germanium rectifiers for the direct replacement of selenium rectifiers in television sets. One 400-milliampere halfwave rectifier 1N1008 and one 400-milliampere doubler rectifier 1N1016 replace the entire line of five replacement types. Both deliver 400-milliampere D-C output current into a load at 70° C. or 158° F. and are rated at a peak inverse voltage of 380 volts and an RMS input voltage of 130 volts.

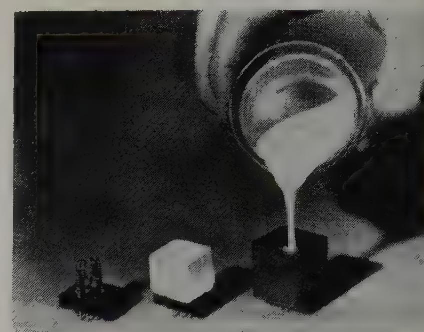
Circle 165 on Reader Service Card



Casting Resin

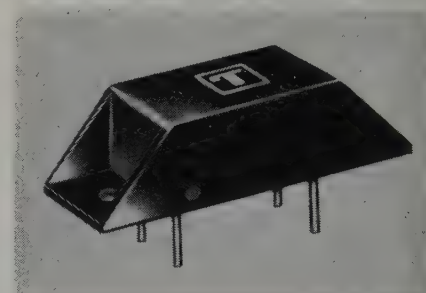
Stycast TPM-4 produced by Emerson & Cuming, is curable in the range of 400°F. to 500°F. It is a rigid, thermosetting plastic and hexagonal steel bars have been embedded and shocked from +300°F. to —70°F. without failure. Shrinkage during cure is very low and thermal stability is continuous at 500°F. The curing schedule is long and slow but simple to accomplish even when large sharp-edged objects are embedded. Write for Technical Bulletin 7-2-1A.

Circle 197 on Reader Service Card



Zener Diode-Transistor Combo

A new device combines in a single package a voltage reference (temperature compensated zener diode) and an amplifying transistor. "Ref-Amp" provides a combined temperature coefficient



as low as .002% per degree C over a temperature range of —55°C to + 100°C. Regulator circuits requiring 10 or more components, may now be designed with one transistor, one Ref-Amp, and four resistors. Write for bulletin TE-1352.

Circle 167 on Reader Service Card

30 VA To 300 VA Static Inverters

These units, designed by Magnetic Amplifiers for aircraft and missile application, utilize transistor and magnetic amplifiers to convert 28V DC to 115V 400 cps 1 phase or 3 phase. Voltage regulation ±3% at zero to full load with input variations of 10%. Frequency output ±2%. The line is extensive and covers other input voltages and output frequencies. Ambient temperature range —55°C to 71°C.

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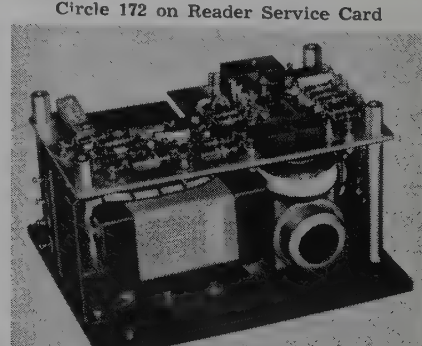

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(*Continued on page 60*)

Industry News

Factory sales of transistors in September increased 20 percent over August—a month in which such sales had attained the highest level in the history of the transistor industry—the Electronic Industries Association recently announced. Unit sales of transistors during the first nine months of this year exceeded by nearly two million the number of transistors sold during the entire calendar year 1957. Factory sales in September totaled 5,076,443 with a dollar value of $10,811,412 compared with 4,226,616 transistors valued at $9,975,935 sold in August and 3,231,-000 units valued at $6,993,000 sold in September a year ago. Cumulative sales during January-September, totaled 30,397,277 valued at $70,230,195 compared with 17,842,300 units with a dollar value of $49,056,000 sold during the corresponding nine-month period last year. Factory sales during calendar year 1957 totaled 28,738,000 units with a dollar value of $69,739,000.

The following EIA chart shows factory sales and the dollar value of transistors in September and the first nine months of 1958:

	1958 Sales (units)	*1958 Sales (dollars)*	*1957 Sales (units)*
January	2,955,247	$6,704,383	1,436,000
February	3,106,708	6,806,562	1,785,300
March	2,976,843	6,795,427	1,904,000
April	2,856,234	7,025,547	1,774,000
May	2,999,198	7,250,824	2,055,000
June	3,558,094	8,232,343	2,245,000
July	2,631,894	6,598,762	1,703,000
August	4,226,616	9,975,935	2,709,000
September	5,076,443	10,811,412	3,231,000
TOTAL	30,387,277	$70,230,195	17,842,300

What is claimed to be the largest industrial chemical research center in Maryland, and the State's 100th industrial research facility was unveiled in Clarksville recently by the 104 year old W. R. Grace & Co.

Located twenty-five miles north of the nation's capital, the $5 million Washington Research Center, of the Grace Chemical Group brings together 250 scientists and technicians formerly located in three different states.

The new Center, which ranks fifth in size among all Maryland industrial research facilities, has been constructed on a 150-acre plot of farmland that permits future expansion. The present two main buildings are the beginning of a research and development center that will eventually be four times its present size.

The electronic action within a transistor was demonstrated in a Texas Instruments Incorporated exhibit which was held for public viewing at the New York Stock Exchange recently. The transistor display was one of several animated representations featured. It represented what is believed to be the first attempt to explain visually in a manner comprehensible to the general public the complex and intricate inner workings of the tiny device as it amplifies an electrical current. The exhibit model was 25,000 times larger than the actual transistor on Texas Instruments production lines from which it was

ied. Other displays illustrated the use of such other electronic products as telemetering, detection and lance, and navigation and control systems for guided siles; radar for airborne early warning defense, and ort and airways control; and sonar, radar and magics systems for anti-submarine warfare.

Iicrowave Associates, Inc., recently announced conuction of a new wing to its plant at Northwest Indusl Park at the junction of Routes 128 and 3 in Burling-, Mass., and upon its completion in March will provide litional space of approximately 18,000 square feet ich, added to the present plant completed in 1956, l total approximately 68,000 square feet. Expanded ilities for engineering and production of microwave es and semiconductors will be provided.

Sprague Products Company, distributors' division of rague Electric, North Adams, Mass., celebrated its 25th niversary this past Fall. Sprague Electric, the parent mpany was founded seven years earlier in 1926. Sprague oducts' initial success was based on its now famous "600 ne" Capacitors. Other developments followed in rapid ccession.

Sprague Products Company offices, now greatly enged, continue at Sprague Electric headquarters in North lams, Mass. Harry Kalker still heads the division as les manager. Robert C. Sprague, Chairman-of-theard of the parent Sprague Electric Company, is a rmer president of EIA and is still a member of that ganizations' board of directors.

Construction of a new 90,000 square foot extension to e local plant of the RCA Semiconductor and Materials ivision was announced recently by Dr. Alan M. Glover, ice President and General Manager. The new structure s been necessitated by the rapid expansion of RCA's tivities in semiconductor products and the Division's itry into new fields including special components and aterials.

A new company to manufacture silicon power transisrs and silicon diodes directed primarily to the military arket has been formed. This organization is Silicon ransistors, Inc., 150 Glen Cove Road, Carle Place, L. I., nd will be headed by Harold Sandler, President, Donald es Jardin, Vice President, Robert Ashley, Sales Manger and Randolph Bronson, Chief Engineer.

An ultrasonic machining service has been announced y Connecticut Instrument Corporation, Wilton, Conecticut. Hard and brittle materials previously considered nmachinable, such as glass, ceramics, sapphire, quartz, arbide, germanium, and many others will be machined o specification. Holes and cavities of nearly any shape an be produced with a high degree of precision by ultraonic machining. C.I.C.'s ultrasonic machining service ives the designer new latitude in his choice of materials nd the amount and type of machining he requires.

Zenith Optical Laboratory announces the expansion of ts Ultrasonic Drilling and Grinding Division at Great Neck Road, Copiague, New York. To meet the ever increasing demands for irregular shaped holes in ceramics, glass, ferrite, quartz, germanium and similar hard metals used by many Industries today, Zenith Optical has added new equipment and larger space to its present facilities. By using abrasives in liquid suspension, Zeniths' Ultrasonic tool is actually never in contact with the work, eliminating any heat being generated and thus preserving the internal grain structure of the material being "drilled."

[*from page 57*]

Dr. Malcolm R. Currie, co-head of the electron dynamics department of Hughes Aircraft Company, Culver City, Calif., has been named the "outstanding young electrical engineer of 1958" by Eta Kappa Nu, national honor society. Dr. Currie, 31, won the award for his technical contributions in the field of low noise electron guns and backward wave oscillator development. Formal presentation of the award will be made in February at a New York meeting of the American Institute of Electrical Engineers.

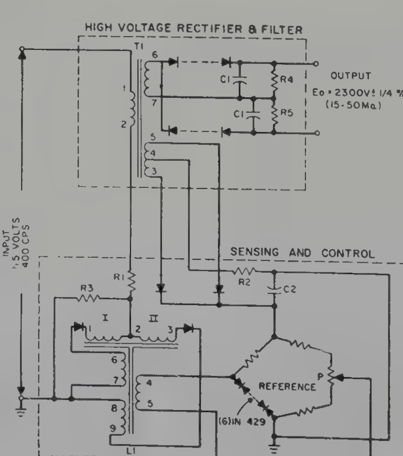
Alfred B. Rossip, formerly industrial sales manager at General Transistor Corporation, is now associated with Electronic Fabricators, Inc. (EFCON), 682 Broadway, New York 12, N.Y., as president of the organization. Mitchel Samuels has assumed the position of vice-president in charge of sales at EFCON. The company is a prime source of precision film capacitors for high reliability applications.

HIGH VOLTAGE REGULATED D-C SUPPLY

A magnetically regulated d-c power supply capable of providing 2300 volts at 15-50 milliamperes with ¼% regulation has been developed at Bell Telephone Laboratories. This power supply was described at the National Electronics Conference in a paper prepared by W. J. McDaniel and T. L. Tanner.

An outstanding feature of the power supply is the isolation of the control and output sensing circuits from the high voltage output. This is accomplished by placing the control element—a self-saturating magnetic amplifier—on the low voltage input side of the regulated supply and by adding an auxiliary winding for the output sensing.

Ruggedness and reliability are assured by employing silicon rectifiers both in the high voltage output circuit and in the voltage reference circuit. A conventional voltage doubler serves as the high voltage rectifier, with sufficient capacitance employed in the filter to reduce



Schematic representation of 2300 volt magnetically regulated power supply developed at Bell Telephone Laboratories.

the maximum RMS ripple to ½% at 50 milliamperes. The reference voltage is provided by a series chain of six 6-volt temperature compensated Zener diodes connected in a bridge circuit.

Nominal input to the power supply is 115 volts at 400 cycles. Output voltage is maintained to the desired accuracy with variations in line voltage from 105 to 130 volts, with load current changes of 15 to 50 *ma*, and over an ambient temperature range of −40° to +85°C. Over a restricted temperature range and with added refinements, this circuit has regulation capabilities of ±1/10%. Measured efficiency at full load is 82%. Both the step-up transformer and high-voltage capacitors are oil-filled. The magnetic amplifier is cast in silica-filled epoxy resin for environmental protection.

NEW GOLD COATING PROCESS

A DOZEN semiconductor manufacturers are reducing their finishing costs through the use of a new gold-coating process called "Atomex," which requires no electricity.

Military specifications for many transistors call for a coating of 10 millionths of an inch of gold on the exterior of the assembly. These assemblies frequently consist of several segments which are electrically insulated from each other. If they are to be coated by conventional electroplating, these segments must be wired together temporarily to complete the plating circuit.

Atomex, developed by the Chemical Division of Engelhard Industries, Inc., eliminates this problem because it provides a satisfactory gold coating without current. The transistors are simply immersed in a bath, or tumbled in it. The process works by ionic displacement. Attacked chemically, the base-metal surface (usually nickel or nickel-plated iron or Kovar) sheds atoms into the bath. These are replaced by atoms of gold from the bath.

According to Engelhard, transistor manufacturers have discovered that the process also has these additional advantages over electroplating:

1. The coating is denser, so that the same properties can be achieved with 35 percent less gold.
2. Since there can be no electrical shielding, there are no low- or high-density areas. All parts of the object, even blind recesses, receive a uniform deposit.
3. The gold actually interlocks with the base metal, providing a much firmer bond.
4. Analytical control of the bath is unnecessary because there is no free cyanide or carbonate buildup. Small operators no longer will have to hire consultants to check their baths periodically.
5. All the gold in the bath can be used up. The spent solution is thrown away, rather than sent back to the manufacturer for refining.

The bath is prepared by simply mixing a 200cc unit of concentrate, containing ½ oz. troy of fine gold, into a gallon of water. Any tank which will resist slightly acid or alkaline solutions can be used, including Tygon, Koroseal, polyvinyl,

(Continued on page 63)

New Literature

Catalog issued by Acme Electric Corp. lists specifications for six popular types of miniature and sub-miniature pulse transformers. Break-away drawings show how these transformers are constructed and indicate the comparative importance of the various types of materials used in the completed unit. A typical pulse shape is shown with annotations indicating all the factors which must be considered in the design to reproduce an input pulse with the best possible accuracy.

Circle 104 on Reader Service Card

A new 48-page booklet, "Transistor Fundamentals and Applications," containing basic information on transistor theory and circuit applications has been published by RCA Semiconductor Products. Subjects covered in the 16-section booklet include: transistor physics; the p-n junction; p-n-p and n-p-n junction transistors; the point-contact transistor; transistor characteristics; types of transistors; transistor amplifiers; methods of coupling; gain controls; power amplifiers; oscillator circuits; power supplies; practical transistor circuits; transistor components, and servicing transistor circuits.

Circle 113 on Reader Service Card

A new supplement has been issued to owners of its Engineer's Handbook by CBS-Hytron, tube and semiconductor division of Columbia Broadcasting System, Inc. The 40-page supplement offers new and revised data for fourteen types as well as eight pages of new and revised curve sheets. An up-to-date table of contents lists more than 500 types now included in the handbook.

Circle 102 on Reader Service Card

Allied Radio Corporation announces the publication of a Semi-Conductor Directory, available to all transistor and diode users. The directory covers about 1,000 transistors and diodes available from Allied's stocks at OEM prices, and produced by 13 major manufacturers (Amperex, General Electric, Hoffman Electronics, Hughes Aircraft, International Rectifier, International Resistance, Motorola, Pacific Semiconductors, Philco, Raytheon, Radio Corp. of America, Sylvania, Texas Instruments). Each transistor, diode and rectifier is listed by part number, name of manufacturer and OEM price in quantities up to 1,000 pieces.

Circle 122 on Reader Service Card

Branson Ultrasonic News, a new house organ devoted to industrial techniques and applications of inaudible sound, is new available from Branson Ultrasonic Corporation. Drawing on twelve years of experience in the use of high frequency sound for gaging, cleaning and testing, Branson is issuing the "News" to exchange information on the latest developments in the field. Questions concerning ultrasonic equipment are invited and technical assistance is offered.

Circle 108 on Reader Service Card

A 4 page catalog has been released by Microwave Development Laboratories which provides an up-to-date guide for the selection of precision cast Topwall Short Slot Hybrid Junctions. This catalog also includes some interesting electrical data and some common uses for these hybrid junctions.

Circle 114 on Reader Service Card

Bulletin no. 213 issued by JFD Electronics describes the characteristics of their new distributed constant delay lines and the models available from stock. JFD is also fully able to accommodate any particular delay network problems (distributed constant or lumped constant) not covered by current JFD models.

Circle 115 on Reader Service Card

Magnetic Amplifiers, Inc. has made available a four page and an eight page color brochure to cover its complete line of (non electronic) Variable Speed Drives for Industrial Equipment motor control. Brochure #s-790 provides Specifications and Engineering Data for drives from 1/15 to 1/8 H.P. Practical control arrangements for local, remote, reverse, and dynamic braking operations are presented. In addition circuit description and schematics are provided.

Circle 120 on Reader Service Card

A 16-page two color illustrated brochure describing the activities of W. R. Grace & Co.'s new Washington Research Center is available on request.

The brochure gives a brief background of the company from its origin in Peru in 1854 to its emergence as an important part of the U. S. chemical industry during the past six years.

Activities described include research in the fields of catalysts, polymers organic and inorganic chemistry, agriculture, process and product development, and research services.

Circle 126 on Reader Service Card

A new 6-page brochure is available upon request, showing Conrad, Inc. walk-in environmental chambers for temperature, altitude, and humidity. The brochure describes complete missile test facilities and components testing units.

Circle 105 on Reader Service Card

om page 61]

ass, or plain uncoated stainless steel.

Atomex has a number of other uses in ectrical manufacture. It can be used to ld-coat printed circuits in order to pro- t the copperfoil from corrosion. Cir- its so treated retain their solderability r 12 to 18 months under ordinary storage nditions. Because no electrical connec- ons are required, they can be coated ter etching. Other applications include ectrical plug connectors and radio nobs.

In addition to nickel and Kovar, the ocess has been tested successfully on pper and copper-base alloys, cadmium, nc, monel, iron, Woods metal, nickel- lver 12%, type metal, steel, lead, tin- ase die-cast alloys, soft solder, pewter, lumel, cobalt, and bismuth alloys. It ndoubtedly can be used on a number other alloys not tested, according to ngelhard Industries. Coatings up to 10 millionths thick can be applied to most metals.

The rate of deposition varies with the type of metal being plated and the temperature. For example, it takes about three minutes at 60°C to deposit 1 mg/in^2 on iron, die-cast metals, steel, or soft solder. At 90°C, it takes one-and-a-half minutes. In the case of copper and certain special alloys, the bath's *pH* must be controlled by adding small amounts of ammonia as necessary.

In general, objects to be plated are cleaned as if for electroplating. In the case of copper-printed circuit boards, however, it has been found that scrubbing with wet pumice or proprietary cleansing powders is better than chemical cleaning.

A few millionths of gold is adequate to protect metal surfaces which are to be soldered. In some applications, the gold coat itself can be used as a solder between such metals as tungsten and nickel.

BOOK REVIEWS

TITLE: Industrial Electronics Handbook

AUTHORS: Staff of Specialists, Edited by William D. Cockrell

PUBLISHER: McGraw Hill 1958

Industrial Electronics Handbook is a monumental collection of information, data, circuits, theory and current engineering practice in the field of applied electronics for industry. Here may be found a collection of the works of many well qualified authors each treating his specific field of specialization. The book omits nuclear electronics and communications, as such, however the scope of the material presented is quite comprehensive.

The first section titled "Fundamentals" is a thorough review of engineering mathematics and basic electrical theory together with a rather complete series of tables of integrals and physical constants. An excellent chapter on feedback control system theory may be found under the "Mathematics" heading.

Section 2 deals with electrical and mechanical control elements. Standards of reference and general principles of operation of tubes, semiconductors, magnetic and mechanical devices are carefully treated. The chapter on transistors is surprisingly comprehensive with a good deal of information calculated to assist the design engineer. The treatment of magnetic amplifiers and mechanical control elements is clear and descriptive.

Sections 3, 4, and 5 deal with Power Supplies, Control Circuits and Circuit Applications. Here many circuits are presented together with a complete analysis of operation. The treatment of High Frequency Heating is especially good.

The balance of the book, sections 6 through 10, round out the general scope of the handbook. There are chapters on both Analog and Digital Computers, test procedures, new production techniques, general uses and military requirements in addition to a list of technical information sources. A very good concise index completes the work.

Industrial Electronics Handbook is a complete, thorough library of information presenting a far more complete treatment of the subject material than is usually encountered in a book of this type. The handbook should provide a fund of information for the electronics engineer and is a worthwhile addition to any engineering library.

TITLE: Dynamical Analogies

AUTHOR: Harry F. Olson

PUBLISHER: D. Van Nostrand 2nd Edition 1958

Dynamical Analogies as the name implies is a treatment of the solution of mechanical and acoustical problems by their electrical analogies. This book is exceptionally comprehensive, treating many machines and systems not previously covered.

The first two chapters deal with definitions and elements in the systems to be treated. A series of tables at the end of chapter two lists the various elements in the four systems in terms of their analogies.

Chapters three and four explain the Electrical, Mechanical Rectilineal, Mechanical Rotational and Acoustical systems in terms of one, two and three degrees of freedom. Here may be found the analogies between Kirchhoffs Law and D'Alemberts principle, comparing the algebraic sum of electromotive forces around a closed circuit to the algebraic sum of the forces applied to a body (equal zero). A complete comparison of the equations of the four systems is made and the equations are shown to be similar and analogous.

Chapters five, six and seven explore corrective networks, wave filters and transient response. Chapter eight is an especially interesting treatment of driving systems. Here Dr. Olson reviews the classical moving coil or dynamic driving system in addition to magnetostriction and piezoelectric driving systems. The balance of the book deals with various applications and specific machines including an excellent discussion of noise and distortion (Chapter 11) and a treatment of magnetic system analogies (Chapter 15).

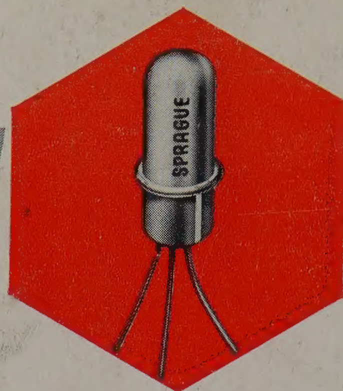
Dynamic Analogies is a thorough up-to-date treatment of many classical problems by analogous systems and should be a valuable aid to engineers and scientists engaged in system analysis.

Stephen E. Lipsky

Index to Advertisers

micro-alloy transistors from SPRAGUE*

NEW



2N393

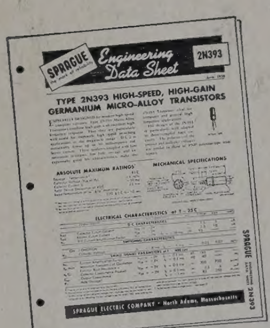
	Min.	Typ.
h_{fe}	40	155
f_{max}	40	60

HIGH-SPEED, HIGH-GAIN 2N393 TRANSISTORS

for modern computer circuitry

Type 2N393 Micro-Alloy Transistors combine high gain with excellent high frequency response to meet demands of high-speed computer switching applications in the megacycle range. Low saturation resistance, low hole storage, and exceptionally good life characteristics make micro-alloy transistors top performers in general high frequency applications, as well as computer circuits.

D-C β is remarkably linear up to 50 milliamperes collector current. The design of the 2N393 is particularly well adapted to direct-coupled logic circuitry. The polarities of the emitter and collector voltages are similar to those of PNP junction-type transistors.



Both micro-alloy and surface barrier transistors are now being made in Sprague's completely new semiconductor facility. Quantity orders for the popular types shown here are shipped promptly. Or get fast delivery on small quantities from your local Sprague Industrial Distributor.

For complete engineering data sheets of the types in which you are interested, write Technical Literature Section, Sprague Electric Co., 467 Marshall St., North Adams, Massachusetts.

* *Sprague micro-alloy and surface barrier transistors are fully licensed under Philco patents. All Sprague and Philco transistors having the same type numbers are manufactured to the same specifications and are fully interchangeable. You have two sources of supply when you use micro-alloy and surface barrier transistors!*

surface barrier transistors

2N128
MIL GENERAL PURPOSE
(MIL-T-12679A)

2N240/SB5122
FOR COMPUTER SWITCHING

2N344/SB101
FOR MEDIUM GAIN AMPLIFIERS

2N345/SB102
FOR HIGH GAIN AMPLIFIERS

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